SKYLAB: THE HUMAN SIDE OF A SCIENTIFIC MISSION

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Thesis Prepared for the Degree of

MASTER OF ARTS

UNIVERSITY OF NORTH TEXAS

May 2007

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Johnson, Michael P. *Skylab: The Human Side of a Scientific Mission*. Master of Arts (History), May 2007, 115pp., 3 tables, references, 104 titles.

This work attempts to focus on the human side of Skylab, America's first space station, from 1973 to 1974. The thesis begins by showing some context for Skylab, especially in light of the Cold War and the "space race" between the United States and the Soviet Union. The development of the station, as well as the astronaut selection process, are traced from the beginnings of NASA. The focus then shifts to changes in NASA from the Apollo missions to Skylab, as well as training, before highlighting the three missions to the station. The work then attempts to show the significance of Skylab by focusing on the myriad of lessons that can be learned from it and applied to future programs.

ACKNOWLEDGEMENTS

This thesis would not be possible without the help of numerous people. I would like to begin, as always, by thanking my parents. You are a continuous source of help and guidance, and you have never doubted me. Of course I have to thank my brothers and sisters. You may be older than me but you have always treated me as an equal and have always supported me.

I owe much to the guidance of Dr. J. Todd Moye. Thank you for going out of your way, and out of your field, to help me with this project. Thank you also to the other instructors at the University of North Texas who have guided the beginning of my graduate work, especially Dr. Adrian Lewis, Dr. Al Hurley, and Dr. Richard Lowe. Since I stepped foot on campus I have been amazed by the quality of professors in the History department.

Thank you so much for all those who worked on the Skylab program. Your hard work and dedication greatly influenced me and kept me motivated, and of course without it this work would not be possible. I would especially like to thank those who took time out of their busy schedules to talk with me: John Aaron, Lee Briscoe, Ed Fendell, Charles Lewis, Zach Kirkland, Gene Kranz, Earl Thompson, and Milton Windler.

Finally, thank you to my many friends who have helped me and put up with me through this procedure. I especially thank Karen DiValerio and my other friends from Space Center Houston, my original inspiration. I thank my Aggie Awakening families for their spiritual support. Last but certainly not least, thanks to the graduate students in the History department who have struggled alongside me, especially Cody, Justin, Brian, Paul, Bianca, the ever helpful and ever patient Lisa, and all the others in the History Help Center.

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INTRODUCTION

When President Dwight Eisenhower signed the National Aeronautics and Space Act on July 29, 1958, he officially created one of the largest and most influential government agencies of the United States. Through this act, the National Aeronautics and Space Administration [NASA] replaced the National Advisory Committee for Aeronautics [NACA] and changed the focus from aeronautics to space exploration.[1] The creation of NASA came almost directly as a response to the launch of Sputnik I by the Soviet Union on October 4, 1957. At this time, the United States and the Soviet Union were embroiled in the Cold War, a major post-Second World War struggle between the democratic and communist nations. After the launch of this first satellite, the United States people felt threatened by the possibility of space being dominated by their rivals. This brought about the need for NASA. The two nations began the virtually unstated but ever present "Space Race" to reach the Moon and conquer space.

The Soviet Union, with its early start, boasted much of the early "firsts" in space travel. On November 3, 1957, Laika, a dog, became the first living thing to orbit the Earth. Yuri Gagarin was the first human in space on April 12, 1961, a major victory in the space race. Alexei Leonov completed the first space walk on March 18, 1965. While the Russians first achieved a number of other accomplishments, NASA was only months behind. NASA truly took the lead in 1968, when the astronauts of Apollo VIII became the first humans to reach and orbit the Moon.

The agency began with rather meager goals. The Mercury Project, with flights from 1961 to 1963, simply wanted to prove that humans could reach space consistently with one-man missions.[2] With the Gemini Program, from 1964 to 1966, NASA slightly expanded its goals. This time each mission would include two astronauts who would demonstrate tasks, such as rendezvous and Extravehicular Activities [EVAs or space walks], that were necessary for missions to the Moon.[3] These first two programs led NASA to a much larger objective.

On May 25, 1961, President John F. Kennedy delivered what would become the most important speech in NASA's brief history. Before a joint session of Congress, Kennedy declared that "I believe that this nation should commit itself to achieving the goal, before the decade is out, of landing a man on the Moon and returning him safely to the Earth."[4] A year later, on September 29, 1962, at Rice University in Houston, Texas, a city which soon would be home of the Manned Spacecraft Center, Kennedy outlined the immediate future of the space program.

> We choose to go to the Moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we will accept, one we are unwilling to postpone, and one which we intend to win, and the others, too.[5]

Later in the speech, he reiterated that "this will be done in the decade of the Sixties." Gene Kranz calls Kennedy's challenge a "marvelous piece of timing" because it gave NASA a goal to conquer and truly placed them at the heart of the Cold War struggle.[6] Of course, President Kennedy's prophetic words ultimately came true when Neil Armstrong set foot on the Moon July 20, 1969, during Apollo XI, effectively ending the space race.

Even before this, and certainly during the Apollo program [1967-1972], another concern loomed in the back of many NASA officials' minds: what follows landing on the Moon? What could possibly live up to the awe and grandeur of reaching another celestial body? From early on, the answer to this question was a space station. In fact, one can trace the idea of a space station back to a story by Edward E. Hale published in 1869-1870.[7] Since then, many incarnations have surfaced. The most outspoken proponent for an American space station was Wernher von Braun, the premier rocket scientist of his day.

Why did NASA conduct the Skylab program? Skylab was America's first and, so far, only space station. One can say this with conviction since the International Space Station [ISS] is, in fact, an international cooperation, albeit run mostly by the United States. Skylab was also NASA's first endeavor dedicated primarily as a science and research mission in space. Certainly some of the goals in the Mercury and Gemini missions pertained to science, but for the most part, NASA used them only as a precursor to Apollo. For all the scientific output of Apollo, the main goal simply was to send men to the Moon and return home safely. The Apollo program was so operations oriented, that some NASA employees thought that the scientists were an afterthought.[8] The Soviet Union attempted a number of smaller Salyut space stations from 1971 to 1986, but Skylab could be seen as the major effort in long-duration space travel until the Russian Mir station in 1986.

When NASA decided to accept scientist-astronauts beginning in 1964, the culture of space exploration may have changed forever. No longer would all astronauts be test pilots who could learn some rudimentary science. Now some would be scientists who could be taught to fly. A "significant" change occurred between Apollo and Skylab because of these new astronauts.[9] Neil Hutchinson, a flight director during Skylab, believed the scientist-astronauts changed the idea of an astronaut, and indeed, even brought more involvement with outside scientists to future programs.[10] Due to these new astronauts, and the nature of the workshop, Skylab allowed NASA to truly research life sciences in space for the first time.[11] The inclusion of scientists to the astronaut corps precipitated this major paradigm shift in NASA's thinking from exploration to science.

Despite the fact that engineers and scientists had contemplated the possibility of a space station for decades, one would hardly think that the program that became Skylab could live up to the notoriety and prestige of missions to the Moon. In fact, history suggests that only missions to another body, such as Mars, could gain as much attention and praise, as well as monetary support. Numerous members of NASA even looked down on Skylab as a waste of time and energy. Some, such as John G. DeFife, an engineer in the Flight Technology Office, considered himself "left behind" when he had to work on Skylab, while others moved on to the seemingly more exciting new Space Shuttle. In fact, he felt as though "Skylab was sort of a bitter time in my NASA career."[12] While certainly not all of NASA agreed with these sentiments, the fact that this attitude was present, along with other evidence, led some to the conclusion that Skylab seemed to be the most forgotten mission.

Historians and authors have devoted a considerable amount of research to the Mercury missions. The public's love affair with NASA's first space program continued especially with *The Right Stuff* written by Tom Wolfe in 1979 and the movie of the same name directed by Philip Kaufman in 1983. The Apollo program is arguably the most popular and most written-about space program, as evidenced by the myriad of publications on the missions and the 1995 box-office hit *Apollo 13* directed by Ron Howard. Even a 1998 HBO documentary miniseries *From the Earth to the Moon* dealt extensively with the Apollo program. Certainly the more recent space shuttle and International Space Station receive their share of public and media awareness. Even the Gemini program received more scholarly research than Skylab. Overall, perhaps only the Apollo-Soyuz Test Program [ASTP] has received as little notice as the Skylab program.

Even so, a fair amount of information is available on Skylab, if one searches in the correct places. By combining the resources of the handful of books and periodical articles, one notices a predominance of scientific and research information. But what of the men who made these missions possible? While the science and space research are clearly important and the main goal of the missions, these would not be possible without the men and women who worked on the Skylab program. Therefore, one can take a more comprehensive look at the human elements of Skylab only after combining the resources and sifting out the immense amount of technical data. The goal of this paper is to make that human side of the mission more public and accessible.

DEVELOPMENT

While the idea of space travel and a space station had surfaced in science fiction writings for decades, one can trace the reality of this technology back only to post-World War II. Germany employed many of the most brilliant minds of the time to create the first rockets used during the Second World War. The United States government later brought many of these same men to America to work on rockets. They formed the basis of NASA.

In 1958, NASA was born as the nation was cultivating its interest in space travel. In June 1959, Wernher von Braun of the Army Ballistic Missile Agency unveiled his Project Horizon to use a spent booster stage as the base for a station, an idea later referred to as the "wet-stage" [or wet-workshop] concept.[1] The wet-workshop called for astronauts to dock with an already used booster stage in orbit. They would then use materials to build a space station inside that stage. Over the years von Braun continually fought for his space station idea, and eventually saw it come to fruition.

The next major step in the formation of a space station came the following year in 1960. Douglas Aircraft Company built a full-size model of a proposed four-man, wet-workshop station. Housed in Empire Hall in London, it was sixty-two feet [nineteen meters] high and seventeen feet [five meters] across.[2] Not only was this a chance for developers to see their ideas in three dimensions, it also was a great publicity tactic to interest the public in such a concept. By building this model, engineers and lay people alike could more easily visualize what previously had been only a completely imaginary and inconceivable idea. Instead this now made it much more realistic and possible.

The idea of an American space station was stalled, however, on July 5, 1960, when the House Committee on Science and Applications stated that the goal of putting a man on the Moon in the 1960's was a higher priority for the nation.[3] This was later compounded by the more public and more influential speech to the same effect by President John F. Kennedy on May 25, 1961 at Rice University, as cited above. Both of these actions, while committing a large sum of money and national prestige toward the space program and in particular the missions to the Moon, destined the space station to a less prominent role. While NASA still allocated some resources to researching possibilities for long-duration missions, the vast majority of time, talent, and funding went to the space race to the Moon. Consequently, few developments would come about in this area until the government and NASA paid more attention to programs outside of Apollo.

One advancement came on March 1, 1963, when officials of the Manned Spacecraft Center [MSC] in Houston, Texas, proposed an idea for a space station using Apollo parts. This station would have a capacity of eighteen astronauts.[4] Three months later, MSC awarded two contracts to study the feasibility of a station, one to Lockheed Aircraft Corporation and the other to Douglas Aircraft Company.[5] Other minor events occurred during this time, but again the focus of attention at NASA was on reaching the Moon.

While some developments in NASA were surfacing on the idea of a space station, the United States Air Force [USAF] announced on December 10, 1963, its plans for a Manned Orbiting Laboratory [MOL] in conjunction with NASA. This plan would use modified Gemini capsules in a combined fifty-four foot [16.5 meter] long research laboratory. The missions could last up to thirty days but not be resupplied or reused. Also, while they would not use any civilian astronauts as NASA had, the selection process and qualifications would be similar to NASA's astronaut corps.[6] Certainly, people outside of NASA noticed the military potential of near-Earth orbit stations. While this particular plan did not ultimately come to realization, one can attribute some important advancements of the Skylab program to the USAF MOL.

Later, a group of twenty individuals comprising the Space Medicine Advisory Group [SMAG] met eight times between January and August 1964 to discuss such elements as life-support, experiments, and design requirements for the proposed NASA station. SMAG proposed that 30- and 90-day missions were too short to study and examine adequately the long-term effects of microgravity and space in general on the human body. In fact, SMAG stated that the mission should last at least one year in continuous orbit, rather than in the series of shorter missions proposed by the MOL program.[7] Two specific findings from this study would later directly affect the Skylab program. First, the SMAG group argued for the necessity of an emergency contingency that could rescue the crew in the case of a crisis. They also suggested a simulation on the ground before the actual missions in space to test the equipment and to understand better the needs of a crew isolated for so long.[8] Similar other groups would, over time, present ideas to aid the formation of a space station. While some were more influential than others, the very existence of such organizations substantiate that this idea was always important, even if not in the national spotlight.

Around this time, the Marshall Space Flight Center [MSFC] in Huntsville, Alabama, began to incorporate von Braun's old idea of a wet-workshop space station into the Apollo program by testing the feasibility of using Apollo systems to build a space station. This fact greatly irked many of the officials at MSC in Houston,[9] because they did not like the idea of the Marshall Center gaining a more prominent role in what they saw as their niche in NASA. Some of these animosities would expand later in the Skylab program. On July 30, 1965, the Apollo Extension System [AES] began researching the idea of using many smaller pieces to build a bigger station than NASA could make with just one piece, a concept that would later be adopted by Russia's Mir station and the International Space Station.[10] This illustrates NASA's habit of revisiting ideas that had originated at earlier points and using them in later programs. On September 21, 1965, NASA Administrator James Webb advised AAP planners to be as flexible as possible, especially at this early stage in development.[11]

The year 1965 also witnessed the formation of the Apollo Applications Program [AAP], an American space station. AAP eventually became Skylab. The following year saw the first mention of the Apollo Telescope Mount [ATM],[12] which, as a major solar observatory, would eventually play a vital role in the Skylab program. On March 23, 1966, NASA announced the first, rather ambitious, AAP schedule, with a total of forty-five launches including nineteen Saturn V rockets and twenty-six Saturn 1B rockets. While the ultimate schedule would absolutely depend on the completion of the Apollo program, the NASA Administration originally planned the first launch for April of 1968.[13] Eventually, they greatly reduced and continuously pushed back the final schedule. One can, however, discern NASA's ambition for a challenging schedule for the space station in these early planning days.

NASA set the roles of the centers of its operations on the proposed station on August 13-15, 1966. MSFC was in charge of the living quarters and lab components, while MSC would handle mission operations, as usual. Both, however, would also concern themselves with the scientific experiments to be conducted on various missions, depending on the make-up of each experiment. Meanwhile, the center at Cape Canaveral, Florida, would handle the payload integration and launch facilities as it had during the Mercury, Gemini, and Apollo programs.[14] All would have to deal with a continuously shrinking budget. The roles of each center would remain relatively the same throughout the program, and each learned to work cooperatively in order to complete the mission successfully.

In the next few years, NASA integrated some new concepts into the program. To begin with, on June 1, 1967, Deke Slayton, then head of astronaut selection, and Chris Kraft, a lead flight director, together announced the plan to first launch the unmanned portion of the station. Later, if the station functioned, NASA would launch the manned missions to the already orbiting station.[15] This, of course, would eventually happen. Perhaps this saved the program, as evidenced later by the almost catastrophic events shortly after launch of the unmanned station. Also, in mid-November, NASA reintroduced the originally rejected dry-workshop concept. This idea was to launch an unfuelled and pre-manufactured station, instead of using an already used Saturn V section for a station that the astronauts would have to build on-orbit.[16] Eventually, this dry-workshop would clearly become more feasible, easier, and less expensive. Almost two years later, in May of 1969, both Wernher von Braun and Robert Gilruth, then Director of the Manned Spacecraft Center in Houston, recommended the dry-workshop over the wet-workshop.[17] Between 1966 and 1970, NASA was trying to work out the details of Skylab, including whether to use the dry- or the wet-workshop concepts and the responsibilities of the different centers. This time has been referred to as the "growing pains" of Skylab.[18] Finally, on July 18, the new NASA administrator, Tom Paine, officially approved the dry-workshop space station.[19] Simply put, due to the number of necessary launches and other impracticalities, the wet-workshop idea was not as feasible as the dry-workshop.[20] In a relatively short period of time, the basis of the station completely changed. Certainly, this was due to the overwhelming amount of advantages of the dry-workshop as well as the influential members backing the idea. This significantly changed the mission for the better and helped the mission work within the ever-shrinking budget.

Over this period of time NASA continuously updated the amount of launches as well as the schedule for them. In December 1966, NASA scheduled the first launch for June 1968 with a total of fifteen Saturn V and twenty-two Saturn 1B launches.[21] The tragic accident of Apollo 1, with the deaths of astronauts Virgil "Gus" Grissom, Edward White, and Roger Chaffee on January 27, 1967, would greatly change the future missions. In May 1967, NASA pushed back the initial launch to at least "early 1969."[22] Two months later, the AAP was down to seven Saturn V and seventeen Saturn 1B rockets, with the first launch no earlier than March 1970.[23] In December, NASA again delayed the launch to April 1970 with three of each Saturn rocket used.[24] NASA revised the schedule once again on June 4, 1968, with the first launch set for November 1970 and with a new lineup of only one Saturn V but eleven Saturn 1B rockets.[25] On July 22, 1969, NASA moved the launch date to July 1972, and reduced the total number of launches to only four.[26] Perhaps these many changes stemmed from the fact that the budget for this project continually decreased, and the schedules and guidelines had to reflect those decreases. It surely was an ever-evolving, flexible program.

On February 17, 1970, NASA officially renamed the Apollo Applications Project as Skylab. The name had been proposed in 1968 by Donald L. Steelman, but the administration waited to change the name due to budgetary reasons.[27] The new name, presumably, was supposed to give the program more credibility and give those involved a better sense of their mission. Also that year, the NASA Administration announced the first full schedule. The unmanned workshop would launch November 9, 1972, followed by the first crew the next day for a 28-day mission. The second crew would launch January 19, 1973, for a 56-day mission, and NASA scheduled the final crew May 1, 1973, for another 56-day mission.[28] In April 1971, NASA rescheduled the launches for April 30, 1973, followed by the first crew May 1, the second crew July 30, and the final crew October 28, 1973.[29] Yet again, NASA announced on April 5, 1973, the seemingly final change. The unmanned mission, named SL-1, would launch May 14, 1973. The next day, the first crew, SL-2, would follow and would return on June 12. The second crew, SL-3, would launch August 8th and return October 3. NASA scheduled the third and final crew, SL-4, for launch November 9, with reentry expected on January 4, 1974.[30]

While the launch schedule would again change due to unforeseen events, this announcement would finally mark the actual date for the initial launch of the unmanned Skylab space station. These many changes highlight the very flexible nature of NASA. Numerous events led to each delay, some more critical than others. All the while, one can see that NASA was striving to find the best, most efficient time to initiate these missions. These many changes also show a project struggling to survive under the numerous decreases in budget and lack of support.

ASTRONAUT SELECTION

In the early years of NASA, the Administration determined astronaut selection based on what the agency needed in the immediate future. Each group filled a certain need. For instance, the very first group, the Original Seven, consisted completely of test pilots to fly the Mercury capsules. Not one of these Original Seven, however, flew on Skylab.

Pete Conrad had the longest tenure of any Skylab astronaut (Table 1 lists the Skylab astronauts). From the Next Nine (the second group of astronauts selected September 17, 1962) came Lieutenant Charles "Pete" Conrad, Jr.[1] On October 17, 1963, NASA selected "The Fourteen," the third group of astronauts. This saw the inclusion of future Skylab astronaut Lieutenant Alan L. Bean.[2] After these selections, there was a hiatus in the selection of new astronauts. Those already in the corps would easily fill all slots needed for the foreseeable future. Conrad flew two Gemini missions and commanded Apollo 12, whose crew also included Alan Bean.[3] Both astronauts were, therefore, the only two experienced astronauts who flew on Skylab. They each had important knowledge for these missions, for just being in space was more experience than the others had gained. This enabled them to successfully command their Skylab crews.

TABLE 1: Skylab Astronauts

Name	Qualification	Group
Lt. Charles Conrad Jr.	USN	Next Nine
Lt. Alan L. Bean	USN	The Fourteen
Dr. Owen K. Garriott	PhD, electrical engineering	Scientist
Dr. Edward G. Gibson	PhD, physics	Scientist
Lt. Cmdr. Joseph P. Kerwin, MD	USN	Scientist
Maj. Gerald P. Carr	USMC	Original Nineteen
Capt. Jack R. Lousma	USMC	Original Nineteen
Maj. William R. Pogue	USAF	Original Nineteen
Lt. Cmdr. Paul J. Weitz	USN	Original Nineteen

NASA decided that they needed to include more candidates into astronaut selection. The idea was to include scientists, instead of just pilots, so that more useful scientific contributions could result from both missions to the Moon and any future missions. On October 19, 1964, NASA officially announced its search for those scientist-astronauts. The criteria included that the applicant must have been born after August 1, 1930, a United States citizen, no taller than 6 feet, and hold a PhD in natural sciences, medicine, or engineering. NASA also expressed a preference for previous flight experience, although that was by no means necessary.[4] Following a long selection process, an announcement of the candidates came June 28, 1965. Included in this group of scientist-astronauts were Dr. Owen K. Garriott, Dr. Edward G. Gibson, and Lieutenant Commander Joseph P. Kerwin, MD.[5] These three scientists would form the core of the Skylab astronauts whose scientific input would set their missions apart from previous missions.

The planned USAF MOL station had its own selection of military officers. MOL astronauts had to have a BS degree and have graduated from the Aerospace Research Pilot School at Edwards Air Force Base, California.[6] When they cut their own program, the USAF asked NASA if the agency would accept any of the astronauts. NASA accepted some of them on April 4, 1966, as part of the "Original Nineteen." These included among them future Skylab astronauts Major Gerald P. Carr, Captain Jack R. Lousma, Major William R. Pogue, and Lieutenant Commander Paul J. Weitz.[7] The largest number of participating astronauts came from this group. This probably stems from their time of selection, for astronauts from earlier classes had already filled almost all the Apollo program slots. When it came time to find jobs for these men, the office working on the space station became the easiest target for most of them.

Their time in the office and lack of earlier flights made them the most likely candidates for filling spots to fly on Skylab missions.

Interestingly, all but two of the Skylab astronauts were military personnel. Of course, the majority of civilian astronauts did not fly until the space shuttle, which allowed more astronauts to fly. Each group filled a certain need, but the qualifications stayed relatively the same throughout. At this juncture of the Skylab program, NASA opened the astronaut ranks to the scientist-astronaut group.

ASTRONAUT BACKGROUNDS

The nine astronauts who lived on Skylab each has his own history.[1] Seven of the nine served in the military before joining NASA, four of whom came from the Navy. The other two astronauts held PhDs.

The nine men came from very diverse backgrounds. The majority asserted that they were always interested in flying. Some were scientifically inclined. Despite these differences, their lives converged while working at the same place trying to accomplish the same goal.

Captain Charles "Pete" Conrad, Jr., was born in Philadelphia, Pennsylvania, on June 2, 1930.[2] His family was well off, and in 1936 he began attending the prestigious Haverford School.[3] Due to his undetected dyslexia and failing grades in history and English, he was not asked to return to Haverford for the 1947-1948 school year, and instead transferred to Darrow, a less prestigious boarding school.[4] This may have benefited him in the long run, however, because the headmaster of Darrow helped Conrad get accepted to Princeton University on a full Navy scholarship.[5] He was one of seven new students to first declare Aeronautical Engineering as a major. In fact, it would prove to be a perfect fit for him since Princeton and Cal Tech were chosen to house jet-propulsion laboratories.[6] He graduated from Princeton on June 16, 1953.[7]

Even from an early age Conrad was naturally curious about mechanical devices. During the summer of 1946, he began working at an airfield near the family home, and it was here that he found his calling to be an aviator.[8] He proved to be a quick study, and on August 22, 1947, Pete Conrad completed his first solo flight.[9] After college, he began his tour with the United States Navy. In 1958, he was transferred to Patuxent River, the home of the Navy's test pilots.[10] Shortly thereafter, Conrad was selected to apply to be one of the first Mercury astronauts. He grew tired of the tests, however, and on the eleventh day he walked out after throwing a full enema bag on the desk of the commander of the Lovelace Clinic, where tests were held.[11]

Conrad began to regret his decision on May 5, 1961, when he saw Alan Shepard become the first American to fly in space.[12] After some persuasion by a friend, he applied again, and NASA finally accepted him into the astronaut corps on September 17, 1962, as part of the "Next Nine".[13] His first space flight began on August 21, 1965, with Gordon Cooper on Gemini V.[14] He would later refer to Gemini V as "eight days floating in a garbage can."[15] He also flew another Gemini mission (Gemini XI) and commanded Apollo XII before joining the first Skylab crew as their commander.

While living in Oak Park, Illinois, Lieutenant Commander Joseph P. Kerwin, MD, born February 19, 1932, became fascinated with science fiction at an early age.[16] After graduating from Holy Cross College with a Bachelor of Arts in philosophy and a pre-med minor, he attended medical school at Northwestern University. The Navy drafted him in early 1958, and he began his instruction to be a flight surgeon.[17] Since he had at least a small amount of pilot training, this helped when he applied to NASA to be a scientist-astronaut.[18] He did work as Capsule Communicator or CapCom for a number of flights before his assignment as the scientist of the first Skylab crew.

Lieutenant Commander Paul J. Weitz, was born on July 25, 1932, in Erie, Pennsylvania. He wanted to be a Naval aviator from an early age, following in the footsteps of his dad, a World War II veteran. Before joining NASA, he met fellow future NASA employees Alan Bean, Jack Lousma, Eugene Cernan, and Ron Evans, inside connections who may have helped him gain acceptance into the astronaut corps. While becoming an astronaut was not one of his main goals, he confessed that he applied since it had the potential to be better than his current job in the

Navy.[19] Weitz joined NASA as part of the Original Nineteen as one formerly in the MOL group. He served as the pilot of the first Skylab crew, completing the group with Conrad and Kerwin. Thus, the first crew, SL-2, consisted of an all Navy crew.

Growing up in Wheeler, Texas, Lieutenant Alan L. Bean, born March 15, 1932, said that he always wanted to be a pilot because he strove to be brave.[20] In high school he joined the Naval Air Reserve to begin his involvement with airplanes.[21] He received a Naval ROTC [Reserve Officer Training Corps] scholarship and used that to attend the University of Texas in Austin. While there, he studied aeronautical engineering to go along with his interest in flying.[22] Once in the Navy, he became a test pilot partially because it was the most daring assignment, but also because it offered him greater variety in experiences and challenges. Similarly, he applied to NASA because he felt the astronaut program would provide the next step in a logical career progression.[23] Bean was selected in "The Fourteen" group in October 1963. His first true NASA assignment was as backup commander to Gemini X with Clifton Williams.[24] Towards the end of the Gemini program he transferred, somewhat unwillingly, to the Apollo Applications Program, the precursor to Skylab.[25] After the untimely death of Clifton Williams, who had been scheduled to fly on Apollo XII, Pete Conrad chose Bean to be his lunar module pilot.[26] He flew on Apollo XII and walked on the Moon with Conrad, making them the third and fourth men to do so. This unique experience certainly helped him gain the renown needed to become the commander of the second Skylab crew.

Dr. Owen K. Garriott, born in Enid, Oklahoma on November 22, 1930, was also interested in space from an early age. While he did join the NROTC,[27] he stayed in school to attain his PhD in electrical engineering rather than join the service. His love for space never died, however, and he trained to secure his pilot license in an attempt to try to help his chances of acceptance by NASA.[28] Garriott was admitted in the scientist-astronaut group. Even though he did have his pilot license, he still had to go directly to flight school with the military in order to get his wings to become a true astronaut.[29] After this flight training, he, like many others, worked in different offices within NASA before learning that he was selected to fly as the scientist in the second Skylab manned mission.

Captain Jack R. Lousma, like many other astronauts, envisioned himself flying from an early age.[30] Lousma was born in Grand Rapids, Michigan on February 29, 1936. After college, he joined the Marines only because both the Air Force and the Navy did not accept married pilots. As a unique way of applying to NASA, Lousma responded to a newspaper advertisement by NASA saying they were looking for new pilots.[31] Lousma joined the team as part of the Original Nineteen astronauts. Skylab was his first time in space. He acted as pilot, joining Bean, the commander, and Garriott, the scientist.

Major Gerald P. Carr, born August 22, 1932, had interests in technology and aviation since he was a young boy growing up in Santa Ana, California.[32] As a result, he joined the Marines with the ambition of becoming an aviator in the mid-1960's.[33] In 1965, he applied to NASA simply to see how far he could get in the process.[34] To his surprise, he was selected as another member of the Original Nineteen. Interestingly, Carr's goal was not to become an astronaut, unlike many of the others.[35] He simply applied because the opportunity arose. Surprisingly, he was accepted. As another surprise to many in the NASA community, the Administration chose Carr as the rookie commander of the third Skylab mission, leading an all-rookie crew, the first since Gemini. This announcement of Carr leading an all-rookie crew upset at least one astronaut. Walter Cunningham, who had worked in the AAP office since 1968 and had flown on Apollo VII, left NASA after he learned that he would not fly on any of the missions and had not received the third commander position.[36] Those in charge of the selection, especially Deke Slayton, must have found some particular qualities and skills that they discerned uniquely favorable about Carr and the other rookies.

Born on November 8, 1936, Dr. Edward G. Gibson was extremely interested in science, especially astronomy, from his elementary school days in Buffalo, New York.[37] While he was a graduate student at Cal Tech, on his way to a PhD in physics, Gibson closely followed the first NASA programs of Mercury and Gemini.[38] When the scientist-astronaut application time arrived, it seemed a perfect fit for the astronomy enthusiast. Gibson joined NASA only after accomplishing flight training with some of the other scientist-astronauts, a time he said was very difficult with "a steep learning curve."[39] Gibson became the third scientist to fly on Skylab. His physics and astronomy background proved invaluable to the solar observations of the mission.

Major William R. Pogue, born January 23, 1930 in Okeman, Oklahoma, was another young boy "fascinated by aircraft." Pogue, one of the older men in the group, actually started flying during the Korean War with the intention of becoming a teacher.[40] Then, in the mid-1950's, a new group of high-performance flyers called the Thunderbirds began touring the nation. Fascinated, Pogue became one of the lucky few who took part as one of these most skilled pilots.[41] He also followed the space race very closely.[42] When an opportunity became apparent, he applied and was accepted into NASA. Pogue entered with the Original Nineteen, and worked in the NASA offices until selected as the pilot of the third Skylab mission, joining the all-rookie crew of Carr, Gibson, and Pogue. Despite their calculated selection, the all-rookie status of this crew received greater critical scrutiny during and after their flight than the other crews, since questionable and unseasoned judgement calls reflected in their mission.

The astronauts of Skylab hailed from a wide variety of backgrounds, from different areas of the country. Most expressed an early interest in either space or flight, and they pursued this interest in their careers. Some, like Kerwin and Weitz, actually knew some NASA astronauts before their selection; this may have helped their application process. One thing is certain: despite their various histories, they all believed in their mission and worked together as a team both within and between their crews.

MISSION CONTROL

NASA moved mission control to Houston from Cape Canaveral in 1965 to support the first EVA by Ed White during Gemini V. The Mission Operations Control Room [MOCR] used for Skylab in 1973-1974 looked much the same as it had during the previous missions controlled from Houston. The following layout is from the vantage point of looking from the front of the room to the back viewing area.[1]

The first row was known by the men of mission control as "the trench." It consisted of Guidance, Flight Dynamics, and a rotating position from left to right. The Guidance Officer [GUIDO] maintained most of the onboard computers. This console had more relevance than before because of the ATM computers.[2] The Flight Dynamics Officer [FIDO] detail worked mostly with orbital affairs and the reentry. He only had to report once a day to check the orbit.[3] The final area contained the Launch Vehicle officer [LV] during the launch, an EVA specialist during EVAs, or the EREP [Earth Resources Experiment Package] officer while it was in use.

The second row has been called the "Systems" row. From left to right, it included the Electrical personnel, a different Guidance officer, the Experiments officer, and Medical Operations. The Electrical, General Instrumentaion, and Life Support System [EGIL] position had previously been known as the Electrical, Environmental and Communications [EECOM] officer. As might be expected, they monitored the electrical, environmental, and instrumentation systems of the workshop and the CSM [Command/Service Module]. Next to them was the Guidance, Navigation and Control System [GNS or GNC] engineer who dealt with guidance and navigation of the workshop and CSM. The Experiments officer [EXP] dealt mostly with those experiments not under the heading of ATM, EREP, or Medical. Finally, the Medical Operations officer [MED OPS] evaluated all medical activities.

The third row was more of a command row, including the Network controller, CapCom, Flight Director, Operations and Procedure, and Communications. First, the Network controller [NETWORK] covered the ground systems. CapCom, formerly short for Capsule Communicator, was one of the backup astronauts who acted as the voice of mission control to the astronauts in space. The Flight Director [FLIGHT] was in charge of all aspects of the mission. His job was to "take any actions needed for crew safety and mission success."[4] The Operations and Procedures officer [O&P] managed mission control procedures and data from Skylab. SKYCOM, or the Skylab Communications engineer, maintained all communications to the workshop. This position, previously known as the Instrumentation and Communication Officer [INCO] gained prominence with the addition of the teleprinter.[5]

The final row consisted of the Department of Defense console, Headquarters representative, Flight Operations Director, and the Public Affairs Officer. A representative of the Department of Defense [DoD] coordinated support for the mission such as pickup after splashdown. The Headquarters management representative [HQTRS] acted as an on-site liaison. The Flight Operations Director [FOD] provided an interface between mission control and the program managers from other centers. The FODs, Eugene Kranz and M.P. Frank, worked twelve-hour shifts throughout the program to continuously man the console. Since they had previously served as flight directors, they could also step in if a flight director could not work due to illness or another reason.[6] PAO, or Public Affairs Officer, kept the media informed of mission details. PAO also served as the "voice of mission control" to the public.

Four teams of controllers worked three shifts a day for the first flight. NASA added a fifth team after the first mission to make the job easier on the flight controllers over the longer missions. A flight director led each team. Eugene Kranz, the manager of the flight directors at that time, chose Milton Windler, Charles “Chuck” Lewis, Neil Hutchinson, and Don Puddy as the first four flight directors. Phil Shaffer led the fifth team.[7] Windler had been a flight director since Apollo 8, but the other four were selected shortly before Apollo 16 so they could receive some education and on-the-job training before the end of the Apollo program. Since he had the most experience, Kranz had Windler transfer from Apollo over to Skylab before the end of the Moon missions. He next had Puddy move over so that he could work on training for the activation of the workshop. Hutchinson began working on Skylab shortly followed by the final two, Lewis and Shaffer.[8] Windler had worked recovery operations on Mercury, Gemini, and Apollo before his transition to flight director.[9] Lewis had been a remote site CapCom during the Mercury Program, while the other three worked in mission control: Shaffer as a Trajectory officer, Puddy as TELMU [Telemetry, Electrical, EVA Mobility Unit Officer], and Hutchinson as GNC.[10] Each had his own specialty which he carried into the Skylab program.

Each team had its own personality, due mostly to the differing personalities of the flight directors. They also each had a team color, a NASA tradition from the start. Windler led Maroon Team, Lewis Bronze Team, Hutchinson Silver Team, Puddy Crimson Team, and Shaffer Purple Team.[11] Some of the teams also had mascots or other forms of individualism. Lewis’ team adopted “Splash Gordon,” a fish in one of the on board experiments. Hutchinson’s team adopted Arabella the spider, another creature from an experiment. Puddy had polka dots because of his many polka-dot shirts, while Shaffer had stripes.[12] Usually when the team began on console, they would somehow portray their team’s significance on the screens at the front of the room. Each day during a mission, the controllers played wake-up music when the crew awakened. Puddy’s team at one point had their own unique song, “Paralyzed,” by The Legendary Stardust Cowboy. This song so irritated the crew that they pleaded the controllers to shut it off.[13] Mission Control made these gestures to try to bond the team and in some cases to help reduce the boredom that can come from a long-duration mission.

During the missions, three teams worked eight hour shifts while the other teams had some time off.[14] During the day, the execution shift completed mission goals with the crew. The night shift planned the coming days. The midnight and early morning shift worked procedures and readied the flight plan for the day's execution.[15] While most controllers seemingly did not have a problem with the scheduling, at least one did mention that Kranz set the rotation backwards as compared to other shift schedules. In other words, teams would rotate from the execution shift to the midnight shift, rather than the other way around.[16]

FROM APOLLO TO SKYLAB

Since Skylab was a major transition in NASA's history, a number of differences made it unprecedented when compared with the previous programs. It was the first long-duration flight in NASA history. The previous duration record had been fourteen days, set by Gemini VII in December 1965.[1] Not only would the first crew double that to twenty-eight days, but the second crew would more than double that again to fifty-nine days, and the third would stay up an astonishing eighty-four days. This distinction offered a major challenge for the controllers in Houston, for they would have to maintain complete vigilance for that period of time rather than the little more than a week per mission they had endured with Apollo. In fact, most of the differences centered around this idea of a first long-duration mission.

Ronald Berry, the Assistant Chief of Mission Design, highlighted three major areas on which his group had to focus. First, they had to create a better model of the Earth and its gravity for the long duration orbits. This led them to study trajectory predictions. Together, those two areas aided them in their consumables predictions.[2] One can see how those three important differences fed off of each other. Consumables were especially important because almost all would be launched with the workshop since the larger Saturn V rocket had more power to boost more weight.

Since Skylab was orbiting the Earth, tracking would pose another difficulty. While Goddard Space Flight Center [GSFC] in Greenbelt, Maryland, managed the tracking,[3] various site locations ranging from Fairbanks, Alaska, to Orroral Valley, Australia, to Corpus Christi, Texas, and many sites in between supported the tracking.[4] Despite this extensive coverage, NASA could not track Skylab for a significant amount of the time. As a result, a recorder saved, on a second loop, their conversations and data that occurred when Skylab was not being tracked, and this was “dumped” down to a ground station when the station passed overhead. Even so, Marlowe Cassetti, Skylab’s Mission Planning Manager, for one, was pleased with the much improved tracking of Skylab when compared to the Mercury and Gemini days.[5] While it is true that there were more stations, from a handful to around twenty-one,[6] the tracking still needed improvement and refinement to attain the status for the current International Space Station.

As already noted, NASA had to update Mission Control [the Mission Operations Control Room or MOCR] in Houston to support the long-duration missions of Skylab. For the first manned mission, MOCR stations had four teams controlling twenty-four hours a day working forty-hour weeks. For the last two manned missions, however, they changed to five teams working five days with two days off.[7] For many of the controllers, this was a difficult transition. To a flight controller like James Mager, the main problem was that Skylab tended to break the family routine, which was extremely troublesome. Instead of working between seven and ten days two or three times a year, as in Apollo, they worked basically continuously for nine months.[8] This difference was, understandably, very difficult.

Some NASA employees took the transition from Apollo to Skylab especially negatively. Melvin Brooks, a systems flight controller, conveyed an interesting view into the psyche of some controllers. He stated that everything in his life led up to Apollo, and that “Skylab was a bit of a setback after that.”[9] He went on to say that “a lot of people were disenfranchised with Skylab. Skylab was kind of boring.” He felt much the same way about the ISS and concluded that the next logical step would have been to move directly on to Mars.[10] Similarly, Donald Gregory, an Executive Officer in the Flight Crew Operations Directorate, called Skylab “anti-climatical.”[11] Jerry Bostick, a respected flight controller, felt much the same way. He, much like many other controllers, wanted to keep going with Apollo missions. Since there was little thought of Skylab as a challenge, especially when compared to Apollo, it was seen as boring.[12] He explained, "we didn't feel like other than proving how long that men could live in space and doing some scientific experiments which most of us non-scientists really didn't understand (or care that) very much about, (unfortunately), I'd have to admit, you know, but it was just pretty boring stuff."[13] Bostick went so far as to argue, unsuccessfully, that trajectory people should not have to stay in the MOCR all the time. According to him, "they [the flight directors] wanted warm fuzzies. The flight director wanted to see people right there."[14] That is why Bostick lost the debate. These are just a few examples of people who had opposition with the move to Skylab.

Not all those who worked on the station felt the same way. In fact, Pete Conrad said a number of times that Skylab was better than going to the Moon.[15] Eugene Kranz said that Skylab was as exciting as Apollo ever was, this coming from the lead flight director of Apollo XI and Apollo XIII.[16]

The space hardware was another area where the duration of the mission played an important role. While much of the hardware was the same as had been used before, a few changes were necessary. For instance, certain rubber seals on the CSM were fine for shorter Apollo missions, but would deteriorate during the longer Skylab missions. These were corrected.[17] NASA also had to change testing for materials on the CSM for a longer exposure.[18] Apparently NASA was so concerned about the powering down and powering back up of the CSM after months, since it had never been done before, that this was another major reason to prepare a rescue mission. The rescue vehicle would be ready to fly if the CSM in space would not cooperate.[19] These issues aside, Raymond Melton, of the Flight Systems Test Branch at White Sands, New Mexico, maintained that "it turns out that most of the designs for the systems on Apollo had been so overdesigned and so conservative and so well done, that even though they were originally made to operate only for a couple of days, they worked quite well when pushed way beyond those limits."[20] He then went on to use the reaction control engines as an example. Thirty-two were spaced along the CSM and used to position the spacecraft. Originally designed only for the ten days of an Apollo mission, they instead were stretched to work the much longer Skylab missions.[21] For the most part, the reused Apollo hardware worked well, with some minor changes, despite the significant change in the scope of the missions.

Most of the high-profile flight directors from the Apollo days did not maintain their positions for Skylab. Many, like Gene Krantz and Chris Kraft, received promotions. According to M.P. Frank, one of the biggest problems in MOCR during Skylab was discipline and keeping focus. Apparently, some of the newer flight directors, namely Don Puddy and Neal Hutchinson, required separation. At the same time, while there was an abundance of work to do in MOCR during Skylab compared to the Apollo program, the mission presented spans of boredom for the flight controllers. Sometimes this routine left them not completely focused on their jobs.[22] Because of the way communications ran, during the times that the controllers and the orbiting station were not connected little could be accomplished and those controllers could grow tired and complacent. This certainly proposed a different situation compared to the Apollo missions.

Hutchinson, meanwhile, attributed some of the harsh transition problems to the tight schedules carried over by MOCR to Skylab.[23] During the Apollo missions, the men lived by a tight, set schedule because there was a limited amount of time on the missions. On Skylab, however, this regime of scheduling remained which left little room for error. These missions were different because the crew needed more time allotted for certain activities like inventory. This took significantly longer than originally expected. These tight schedules would definitely hurt the image of the third and final crew.

NASA also had to change its approach to such essentials as hygiene, waste management, and eating, among others. A major psychological difference came from the change in a lengthy rather than a short trip. Lousma likened Skylab to a remote outpost compared to Apollo's camping trip, in that the Skylab astronauts were alone for weeks on end, whereas Apollo astronauts were alone only for about ten days.[24] The astronauts had to prepare for an extended stay together without a great deal of interaction with other people and the outside world. Certainly there is a major difference in the approach to the two drastically distinct programs, and NASA had to review all perspectives and aspects.

One problem for Skylab that did not necessarily stem from the length of the mission was the budget. For the most part, the government granted the Apollo program whatever amount of money NASA needed to reach the goal of the Moon. Since 1970, NASA's budget was cut in a reflection of the country's perception of the space program. Whereas the Apollo program had plenty of money, with Skylab came a program with "a more disciplined budgetary tracking period."[25] This new budgetary phenomenon made those working on the program think in more disciplined terms. For instance, Marlowe Cassetti's division chief, John Mayer, gave him no more than one hundred people to accomplish his tasks in Skylab, although this may also be attributed to Meyer's general disinterest with Skylab. This was a great reduction in manpower from the Apollo days, when Cassetti could hire as many people as needed to accomplish the task.[26] As another example, it was deemed necessary to include a fire hose in the case of a fire. The initial proposal for a fire hose was deemed too expensive by Kenneth Kleinknecht, the head of the program. People laughed when someone suggested a garden hose. After some thought, engineers purchased a $20, 75-foot [23-meter] garden hose from Sears and Roebuck. They outfitted it and put it through pressure tests. After it passed, the mission planners settled on the

$20 hose rather than the $160,000 version proposed by the engineers in Huntsville.[27] An innovative solution saved hundreds of thousands of dollars which, while small in the scope of the budget, could add up over time.

Inter-center rivalry was another issue that did not necessarily stem from the duration of the program. Whatever conflicts may have surfaced in earlier programs were exacerbated by the nature of the mission and the dispute between the Marshall Space Flight Center and the Manned Spacecraft Center [renamed Johnson Space Center, or JSC, in 1973] over control of the program. While some who worked on the program maintained relationships were peaceful between the centers, enough individuals have mentioned it that it merits discussion. For instance, William Easter, the GSFC liaison to JSC, spoke of the "turf wars" between Huntsville, Houston, and Cape Canaveral, as a "battle royale to see who would do what."[28] Ed Fendell, in charge of communications, referred to the conflict between Marshall and Johnson as "sandboxing."[29] Each center tried to grab as much territory as they could and call it "theirs." Marlowe Cassetti tried to explain this by talking about the differences in the structure of the centers. He claimed Marshall was more compartmentalized and its labs did not work together. Each lab even had independent research budgets. At Johnson, however, the labs worked together more closely.[30] These turf wars probably did occur, to some extent, but perhaps they can be understood as people fighting to keep their jobs.

Another disadvantage for Skylab as compared to Apollo came in the form of television coverage. Television executives during the Apollo missions asked NASA to schedule the missions for better viewing times. When planning the Skylab missions, trajectory controllers tried to have a landing at six o'clock Eastern time. Instead, a major television company told them not to interrupt prime time television for something as mundane as Skylab's splashdown.

NASA acquiesced to the television channels.[31] Implausible as it may seem, Skylab's priority was so low, they had to change the schedule to accommodate the television audience.

Skylab, Henry Cooper concludes in *A House in Space*, was "not suspenseful, like the expeditions to the Moon, but a steady, continuous experience, like life anywhere."[32] To change that analogy a little, if Skylab were a year in school, an Apollo mission was a final exam. Or again, if Skylab were a baseball season, an Apollo mission was the playoffs. Baseball seasons are often described as a marathon rather than a sprint, another appropriate analogy. As Robert Heselmeyer, a flight controller, said, "the biggest difference was getting ready for a marathon instead of a sprint."[33] All of these are to say that Skylab became an everyday routine, where one day was spent much like the next, whereas on earlier missions, each day was different for one reason or another. Each program had different specific goals, and NASA planned the missions appropriately to reach those goals. Skylab was NASA's unique marathon.

TRAINING

By the end of 1966, a number of the astronauts who would later fly on Skylab were already part of the AAP office. The Administration named Alan Bean Chief of the AAP Branch in the Astronaut Office in August, and Owen Garriott Chief of the Experiments Branch in October.[1] Also working in the office were Kerwin and Gibson, among others.[2] By May 1967, NASA handed technical assignments out.

TABLE 2: Skylab Crew Branch Assignments

Crew Member	Assignment
Alan Bean	Chief of AAP branch
Owen Garriott	Communications
Edward Gibson	Crew quarters layout and controls
Joseph Kerwin	Food, waste, and IVA
Jack Lousma	Activation and deactivation
William Pogue	Lighting and photography
Paul Weitz	Experiments, AAP 3 and 4

Other astronauts led other important branches including Joe Engle for IVA [Intravehicular Activity] equipment, Bruce McCandless for Experiments on AAP 1 and 2, and F. Curtis Michel for hand holds, tethers, and foot rails.[3]

Once the Apollo program began to slow down, the AAP office began to change dramatically. Before the end of Apollo, most of the astronauts not associated with those missions tried to train wherever they could, whenever they could. For instance, in 1969, Gibson, Kerwin and Weitz were able to simulate an EVA in the water tank at Marshall. They simulated an ATM film canister replacement EVA,[4] something that would greatly help later Skylab missions. After his successful Apollo XII mission, Pete Conrad became the Chief of the (newly named) Skylab Astronaut Office in August of 1970.[5] This addition seemed to bring a little more credibility to the program with a clearly appointed leader. Certainly a program struggling for respectability and funding could use a man like Conrad who was very well respected in NASA.

It was not until January 16, 1972 that NASA announced the official crew assignments (listed in Table 3).

TABLE 3: Crew Assignments

Flight	Prime	Back-up
SL-2	Conrad, Kerwin, Weitz	Schweickart, Musgrave, McCandless
SL-3	Bean, Garriott, Lousma	Brand, Lenoir, Lind
SL-4	Carr, Gibson, Pogue	Brand, Lenoir, Lind

Vance Brand and Don Lind would also train for rescue operations. Likewise, the back-ups would serve as CapCom for each flight.[6] Even though Deke Slayton did not make the official crew assignments until this late date, the astronauts would end up training together for approximately five years. Now that they received official assignments, they could train more thoroughly as a complete crew.

The location for training the Skylab crews became an issue. Since Marshall Space Flight Center was the home of Skylab, much of the initial training occurred at MSFC. Dean Grimm, Chief of the Flight Crew Integration Division, and Deke Slayton eventually won their argument and centralized the training at the Johnson Space Center in Houston. This change meant that NASA had to ship the trainer from Huntsville to Houston, and build a special dock at JSC just for that purpose. They then had to knock down part of Building 7 in order to place the simulator indoors.[9] NASA moved training to Houston presumably to make life easier on the astronauts and controllers, since that was their home, but rivalry among the centers also played a part.

For the first few years of training, the biggest problem was that the Apollo missions, still in progress, had precedence. The Skylab crews, including the backup crews, would have to fight for time on the trainers when they could. Because of this, they had to train in a compressed time frame, a situation that was very different from the Apollo missions. This was potentially problematic.[9] In all, the astronauts received around 2,150 hours of training before launch, including everything from equipment to exercise to briefings. While specialized training began in January 1972, it was not until November that NASA linked up the simulators and trainers with MOCR for complete training. Most of the training at JSC occurred in the high-fidelity mockup of Skylab that was hooked up to the MOCR. They could simulate just about everything from experiments to habitability to docking, all in real time using an IBM 360/65 computer. The only real complaint from the astronauts coming back from Skylab was the comment that the solar observation simulation did not look like what they really saw in space.[9]

While each member of the crew had specialties, each member received training in every aspect of the mission in the event of an accident or illness. For example, each learned how to perform minor surgeries.[9] Training for various activities occurred in many places other than Houston, including medical training at Shepherd Air Force Base in Wichita Falls, Texas.[13] The second and third crews took a fifteen-hour course on Earth observations using the EREP and hand-held cameras, set up by George Maul of NOAA [National Oceanographic and Atmospheric Administration] and Robert Stevenson, the Scientific Liaison Officer of the Office of Naval Research at NASA.[14] This cross training could prove essential for a successful, long-duration flight. The extensive training could also prove helpful for crew morale and simply getting to know each other. The longer they could work and train together, the better they would feel about working together.

Another indispensable phase of the training did not even include the Skylab astronauts. NASA authorized the Skylab Medical Experiment Altitude Test [SMEAT] in December 1970 as a ground-based, 56-day simulation of Skylab.[15] The crew members, who included Bob Crippen as Commander, Bill Thornton, MD, as Science Pilot, and Karol Bobko as Pilot, experienced full training comparable to the real Skylab astronauts, only in condensed form.[11] The simulation itself ran from July 26, 1972, to September 20, 1972. They simulated the confinement, the equipment, the food systems, and the reduced atmosphere, just about everything save for the lack of gravity.[12] The astronauts completed tasks just as performed in space, including all medical experiments.

NASA drew some important lessons from this simulation. For instance, they found that the Urine Volume Measuring System was too small and leaked, something they obviously needed to fix before launch. They also learned how to work together in a closed area for a long time. They had to remain focused on the assignment to accomplish their tasks and overrule their disagreements.[12] SMEAT also saved the astronauts in Skylab from having too fixed a diet. Originally, for the medical experiments, the astronauts would all eat the same amount of calories each day. While theoretically this may be practical, in reality, every person has his own daily need. Some of the more robust astronauts needed more calories while some smaller astronauts needed less. Thankfully for them, the doctors realized the truth behind the matter, and they tailored each diet to the individual astronaut.[13] This extremely important lesson proved invaluable to those who worked on the station. This type of simulation was vital to NASA for it gave an idea of what the astronauts might experience over an extended period of time in space. Certainly nothing NASA had done up to that point could compare to these simulators. These lessons, weighty or not, helped Skylab run smoother. By the end of SMEAT, most of NASA was ready for the launch of its first space station.

SKYLAB LAYOUT AND EXPERIMENTS

The launch of the unmanned Skylab space station marked the end of an era. On May 14, 1973, NASA launched the last Saturn V, the workhorse of the Apollo program, and the largest rocket ever produced. A typical Saturn V was 364 feet (110.9 meters) tall and weighed 6.7 million pounds (3.04 million kilograms). The first stage could generate 7.5 million pounds (3.4 million kilograms) of thrust.[1] The Saturn V had used all of this thrust to reach the Moon. A launch of a Saturn V proved a powerful example of man's scientific ability.

For Skylab, NASA modified the Saturn V. Since Skylab did not need as much power as needed to reach the Moon, NASA engineers converted the third stage into the Skylab workshop instead of the typical fuel storage tank as originally designed. The Lunar Module [LM] was also jettisoned. The Saturn V for Skylab instead stood only 333.7 feet (101.7 meters) tall and weighed 6.2 million pounds (2.8 million kilograms).[2]

The Saturn 1B rocket was like a miniature version of the large Saturn V. The Saturn 1B was a two-stage vehicle, rather than three-stage. It also was only 223 feet (68 meters) tall, so for the three Skylab launches, a 127 foot (38.7 meters) tall "milk stool" brought the vehicle up to the appropriate height for the tower built for Saturn V rockets.[3] A Saturn 1B, when fully ready for launch, weighed around 650 tons.[4] While slightly less impressive compared to its behemoth cousin, the three Saturn 1B launches sending a total of nine men to Skylab must have been amazing enough.

The dry workshop was a station converted from a third stage of the Saturn V rocket. For the first time, NASA engineers and scientists discussed the living conditions and habitation of a space vehicle.[5] Before Skylab, habitation had not been a concern since the missions lasted a relatively short period of time and living arrangements contained only the necessities. For a longer mission, however, the astronauts would have to live and work in this area for an extended period of time, so a certain amount of comfort seemed necessary. One addition that the astronauts continuously had to fight for was the window. By definition, a glass window immediately threatens the structural integrity of a space vehicle, especially one traveling at such speeds and bearing such overwhelming forces to leave the atmosphere. Engineers thought a window was too risky, but the astronaut office was adamant. In the end, NASA decided to add the window on October 31, 1969.[6] This struggle proved that NASA would listen to the astronauts' wishes to make the station more comfortable and habitable. Throughout the Skylab program, NASA reaffirmed numerous times the merit of the window, both for entertainment and for research.

Skylab used the same Command/Service Module [CSM] as the Apollo missions, and this docked to the Orbital Workshop [OWS] of Skylab at the Multiple Docking Adapter [MDA]. The MDA measured seventeen feet (5.1 meters) long, ten feet (three meters) in diameter, and weighed 13,800 pounds (6,210 kilograms). This area housed control panels for solar observations and Earth observations, as well as spare parts and stowage. The Airlock Module [AM] was located between the MDA and the OWS. It measured approximately seventeen feet (5.1 meters) long, a maximum diameter of twenty-two feet (6.6 meters), and a mass of 49,000 pounds (22,050 kilograms). The AM contained the EVA hatch, which was actually a spare from the Gemini missions, and the Instrument Unit for the activation of the Skylab workshop.

A modified third stage of the Saturn V rocket, the Orbital Workshop [OWS], was the main area of Skylab. The OWS was forty-eight feet (14.4 meters) long, twenty-two feet (6.6 meters) wide, and weighed approximately 78,000 pounds (35,100 kilograms). The OWS included the majority of the living area, including the sleeping and eating areas, most of the experiments, and the trash airlock. The Skylab with CSM attached measured 117 feet (35.7 meters) long, weighed 199,750 pounds (90,604.6 kilograms), and had a habitable volume of 12,700 feet cubed (372.2 meters cubed).

Designers located the Apollo Telescope Mount on the outside of the MDA using it for solar observations. The ATM included four solar arrays that would provide about half of the electrical power to the station, with the other supplied by the larger solar arrays located on the OWS itself.[7] Also located in the MDA, the Earth Resource Experiment Package photographed the Earth for various experiments. The training module housed at Space Center Houston [SCH], in Houston, Texas, and the second Skylab station at the Smithsonian Institution National Air and Space Museum in Washington, D.C., provide a better understanding for the size of the station. Pictures and words on a page hardly can do justice to this remarkable engineering achievement.

Due to the longer duration of Skylab, some engineers at NASA believed that some kind of protection was needed against micrometeoroids. Burton Cour-Palais, a specialist in meteoroid sciences and hypervelocity impact physics, proposed an idea for an "outer skin" to stand five inches off the surface of the workshop. During launch, however, it was placed flush against the side of the vehicle in an attempt to keep air pressure from building up and ripping it off.[8] Thermal engineers saw the design for this shield and felt like it could have another role. They saw this as a perfect outer layer to work in conjunction with the protective layer of the skin of the workshop to block heat from the sun. Without this shield, however, an extra layer of protection that the thermal engineers deemed necessary would leave the workshop extremely vulnerable to the sun. John Aaron, an EECOM during Skylab, speculated that had the shield been called the thermal shield rather than the meteoroid shield, and therefore had a subconsciously more important role, more attention would have been paid to its development and placement for launch.[9]

One of the most influential and important areas of research from Skylab was the solar astronomy that came from the ATM. Time on the ATM was in high demand, but those in charge of scheduling had a unique way of dealing with it. Planners gave interested parties a set amount of hours in which to do their observations. Then they could decide what they wanted to do with that time.[10] One of the astronomers, Dr. Richard Tousey, was so concerned about the experiments that he petitioned to be able to talk directly to the astronauts. Of course this opposed NASA procedures, under which only the CapCom talked to the astronauts. NASA officials, however, compromised and allowed astronomers to talk once a week with the astronauts to prepare for the coming week. In the end, Dr. Tousey never did talk to the astronauts, though some of the people he worked with did.[11] He simply did not want to be told that he could not talk to them. Struggles like that happened often in an area where large egos were involved. ATM work consisted mostly of solar observations. With the third crew, however, Comet Kohoutek received at least some part of the observations.

Medical experiments played another important role in Skylab science. A lower-body negative pressure experiment could test, among other things, blood pressure and heart rate. Scientists then compared these findings to tests on Earth to determine any differences. A bicycle ergometer measured the astronauts' metabolic rate. Various experiments required regularly taken blood and urine samples.[12] These medical experiments would test the effect of long-duration space travel and scientists could apply them to future missions. For the most part, the medical experiments confirmed what scientists had previously believed about life in microgravity. Some friction existed between the medical community and the controllers and the astronauts. Many times the medical people wanted more information, but the controllers were unwilling to ask the astronauts for personal information. Richard Johnston, Director of Life Sciences, acted as a mediator of sorts between the medical experimenters and the controllers. He believed that the medical people were marginalized and not shown proper respect by the other controllers, though they were just trying to do their job.[13] They did work out some of the friction, however, by the end of the program.

The EREP consisted of the final area of major scientific experiments on Skylab. With EREP, for the first time NASA made a significant effort to study the planet. The EREP experiments were so important that the orbit of the workshop was aligned in such a way to make the most of those experiments.[14] While some of the ATM systems were automatic, the EREP was strictly manual.[15] Don Lind served as a sort of liaison for the crew interface of the EREP.[16] Charles Harlan became the head of the Earth Resources Aircraft Program. This program would fly any number of planes at the same time as an EREP pass, and they would perform much the same functions as the EREP only at different altitudes. This way they could correlate the findings from the aircraft with those of the EREP on Skylab.[17] Engineers built a new film vault in order to cope with the longer periods of contact with radiation in space. The vault weighed some 2,000 pounds (900 kilograms) to store all the film and to provide protection against radiation. Another interesting aspect is that the orbit allowed for coverage of northern areas that the astronauts had not had an opportunity to film during earlier flights. This meant that more of North America and Europe could be studied.[18] Sometimes events on the Earth affected EREP observations. During this time, the French were conducting some experiments, presumably with nuclear devices, that if viewed by an astronaut through the equipment could lead to blindness. The planners, therefore, had to warn the astronauts if there might be some activity or schedule observational passes around such events.[19] NASA had to consider many details when hosting Earth resources experiments.

Scheduling of experiments became an important issue every day of Skylab. The controllers themselves did not want to decide the importance of each experiment. Every night, during the night shift, planners met to discuss the coming day's schedule. Talks became so heated that they needed a mediator. NASA chose Robert Parker, a scientist-astronaut, to moderate among the different disciplines. Bill Lenoir later worked in this capacity as well. He earned the title, the "Science Czar." For the planners, the medical people were easiest to deal with since they had priority. They, for the most part, received whatever time they required. The solar physicists and EREP personnel, however, never seemed to have the time they wanted to complete their experiments.[20] In the end, the experiments exceeded NASA's planned output.

Since controllers would be deciding on daily schedules only days in advance, NASA engineers added a teleprinter so the astronauts could receive those plans. The paper was only about two and one-half or three inches wide.[21] Controllers had to place all written transmissions on this paper. Since the controllers were so busy with the mission, and perhaps were not proficient with typing, Ed Fendell brought in secretaries from all over the center to transfer communications to the teleprinter. He eventually assigned Shirley Hinson to manage that task.[22] In this way, they allowed employees who may not work as closely with a mission to have a direct hand in it.

To help the scientists, NASA built the first Payload Operations Control Centers [POCC] in Building 30, the mission control center. Each of the ATM, medical, and EREP crews could have their own room for the first time.[23] In addition, NASA built a Flight Operations Management Room [FOMR] to replace the previous Spacecraft Performance Analysis room

[SPAN]. The FOMR could hold meetings for management decisions, and in the case of Skylab, it also helped to integrate the interested members from Marshall Space Flight Center.[24] These types of rooms are still used today for the shuttle and ISS.

For the first time in NASA's history, habitability in the OWS became an important topic before the program. The workshop was large enough that the astronauts each had their own individual sleeping compartments, a feature still unique to Skylab.[25] This allowed for more personal time and at least a perception of being able to remove oneself from the days activities. Clothing also changed drastically from earlier flights. The astronauts now had a choice in their clothing. With zip-off sleeves and pant legs, the astronauts could customize their clothing and be more comfortable. Adaptability became the key to the clothes design. The brown coloring, though, left something to be desired. That unattractive feature can be blamed on the necessity of flame-retardant materials.[26] For Conrad, a veteran of the Apollo program, a number of habitability issues made Skylab better. Microwaveable food, real showers, waste management, and more comfortable clothes highlight his list of improvements.[27]

One should also recognize the food on Skylab as another area of improvement. A study in 1972 concluded that the following food problems would have to be addressed: "extended storage times, variations in storage temperatures, no opportunity to resupply or change foods after launch. . . first use of frozen foods in space, first use of a food-warming device in weightlessness, relatively small size of production lots requiring statistically valid sampling plans, and use of the food as an accurately controlled segment of sophisticated life science experiments."[28] All food launched with the workshop, so NASA had to fully attend to all these problems before that launch. There were sixty-nine different varieties of food for 420 days plus a fifteen percent allowance for variations. They stored all food in aluminum cans to help preserve it.[29] By adding food warmers, the astronauts would have a greater variety and better quality of food available for consumption while in space.[30] One of the more difficult aspects of the food situation arose because it was a major part of the life sciences studies on humans in long-duration space travel. While an original plan called for a control on all food, the administrators decided to give the astronauts some freedom in their food choices. Thus, they only controlled six nutrients. The diet for each astronaut began twenty-one days before launch and concluded eighteen days after their return from space.[31] The food planners also had to keep in mind waste management, and therefore created a comprehensive list of foods to avoid for waste management reasons. These foods included grains, cheese, excessive fats, fried food, milk, excessive sugar, and certain fruits and vegetables.[32] Scientists had to account for a myriad of aspects when preparing foods for long-duration space missions.

The astronauts and those on the ground constantly monitored the food, like most aspects of the program. Sometimes the people in charge of the food did not hear what they wanted to hear from the crews. For example, in a memo on the food dated July 11, 1973, they complained that "the SL-2 crew seems to be groping for information and probing the system for faults. Numerous misconceptions are being bantered about including: a. 'Chili is no good' this is not true – the chili is in excellent condition."[33] Apparently they did not appreciate that the first crew was doing their jobs by reporting problems and dislikes. They also seemed to have missed the point that while the chili may have been in good condition, the crew simply did not like its taste. The report goes on to remark that the second crew was "counteracting rumors that food is bad – especially corn, chili, and bread."[34] Since this came from a biased source, it may be construed that the people in charge of food were simply trying to keep their jobs by downplaying any negative feedback and highlighting compliments. While not perfect, the food was better than on previous programs and the staff would upgrade the food for future programs.

One final area of improvement for the crew was entertainment. Due partially to the longer duration of the missions and partially to the loosened schedule as compared to Apollo, the NASA habitability planners could include some things to help the astronauts stave off boredom. The astronauts themselves were given some freedom to purchase items. Pete Conrad, for one, brought some maps to help aid his Earth observations through the large window.[35] They were also given entertainment kits. These included, among other things: Velcro darts that did not work well because of the lack of gravity, books for reading, a cassette player, and, amazingly, fire-proof playing cards, probably the only such deck in the world.[36] Each astronaut gave the technicians a playlist of sorts so that the staff could make cassettes for use in the workshop. Conrad asked for such artists as Jeanne Pruett, Loretta Lynn, Conway Twitty, Charlie McCoy, Johnny Cash, Glen Campbell, Patsy Cline, and Dean Martin.[37] Kerwin requested mostly classical music, such as Baroque music, Brahms, and Ravel, and showtunes, like *H.M.S. Pinafore*.[38] Weitz, meanwhile, had a more eclectic taste with the Sons of the Pioneers, Johnny Cash, the Mormon Tabernacle Choir, Beethoven, Henry Mancini, Andy Williams, Wayne Newton, and Pat Boone among his recordings.[39] These lists show once again how the astronauts came to the mission from vastly different backgrounds, but were able to come together on a common pursuit. This is not to say that the astronauts were only up there to have fun. They were, however, allowed an hour or so each day to relax and to help ease the stress of the missions.

SKYLAB I

At 1:30 p.m. Eastern Daylight Time on May 14, 1973, the Skylab workshop lifted off into the heavens to orbit the Earth. Just seconds after takeoff, Mission Control in Houston, Texas, began tracking the station for the first of hundreds of afternoons. This afternoon was unusual, however, but not just because it was the first and last launch of its kind. Only about a minute into the flight, Skylab was already in danger. At that moment, controllers knew that the shield to protect the Skylab from micrometeoroids and thermal damage deployed well before it should have.[1] Events began to unravel quickly that would change the course of the mission.

Just sixty-three seconds into the flight, the force of the launch into space had prematurely deployed and ripped off the micrometeoroid shield. Then, approximately ten minutes into the flight, part of the solar arrays broke off and were unable to deploy correctly.[2] This caused many problems for NASA. The solar panels would not generate the required amount of energy. Until they fixed this problem, any crew living on board would have to operate at less than full power. The bigger problem was whether or not a crew was capable of living on board at all. NASA had also designed the shield to block the intense heat of the sun. Without this, the station quickly heated up. With no shield, the heat would make it almost impossible to inhabit. Also there was little to no protection against small fragments, micrometeoroids, that might impact the station.

NASA notified the astronaut crews about the circumstance as quickly as possible, each of them in different ways since most had already left the launch site. Whatever the concern of the others, Weitz maintains that he was confident that at least the first crew would fly, if only just to take pictures of the wounded station.[3] While some may have expressed concern that the mission was a lost cause and they would lose their chance to fly, Lousma had a rather optimistic approach. He said that after he heard about the problem, his reaction was that it could be worse, and that they just had to find a way to fix it.[4] What followed would be, perhaps, the most intensive inter-center cooperation to fix a problem in the history of NASA.

Engineers and scientists from all over the space agency worked together to help solve the problem. Kerwin and Schweickart, among others, headed directly to the large pool at Marshall to work on the various options proposed. They resolved to test each option in the near-weightless environment of the pool. Meanwhile, they also had to find out how to fix the solar array problem. Fortunately, on May 22, Weitz demonstrated that he could free the array by releasing the debris in a method comparable to using a large pair of garden shears.[5]

Two solutions to the lost shield problem quickly became the most favorable. The engineers in Huntsville came up with an awning concept. The astronauts, flying in the command and service module just outside the workshop, could deploy an awning over the workshop to act as a shield.[6] The engineers in Houston felt this was too complicated, since nothing like it had been done before, so they decided to try something else. Jack Kinzler, the Chief of Technical Services, thought of a more simple solution: a parasol. Using an empty camera box on the side of the Skylab, the astronauts could set up a telescoping fabric shield that could deploy over the surface of the workshop and function in a way similar to the missing shield. Kinzler would win the highest NASA award, the Distinguished Service Medal, for his parasol concept.[7] Due mostly to its simplicity, the final agreement was to develop the parasol and send it up with the first crew. The material used for the parasol, however, would not last for the duration of the mission since it could last in ultraviolet radiation for only a short duration. As a result, Marshall’s awning would eventually replace the parasol.[8]

Developing the parasol in about ten days required an immense amount of cooperation between JSC and MSFC, as well as many long hours by the engineers involved. For instance, Fred Rowell was the lead man in the shop who worked on the metal and welding for the parasol.[9] One of the first and most important steps in this act was to test materials and to come to a solution as to what materials to use. Aleck Bond, the Assistant Director of Chemical and Mechanical Systems, helped to coordinate this process.[10] James McClane, who worked in vacuum chambers of Building 33 as part of the Space Environment Test Division, was one of the individuals who helped to test the degradation of the materials used on the parasol.[11] James McBarren, who worked mostly on the space suits, helped to set up an area at Marshall to sew together the parasol and awning. In fact, he had to call up a manufacturer on a Friday night for 500 yards of aluminized Mylar. The next morning, by special delivery, the Mylar was in place.[12] Kenneth Young, head of Orbital Design, worked overtime to work out a rendezvous problem. NASA officials decided that the first crews' rendezvous with the workshop would need to occur in daylight somewhere over Hawaii or the continental United States so that the ground crew could have live video. Young and others worked almost double their normal hours in order to make sure they had all the specifications correct.[13] These are just a few examples of the myriad of "unsung engineers" who came together in this short period of time to find a solution to a major problem.[14]

While all this work was going on, the flight controllers still had to control the workshop as it orbited. NASA assigned half of the mission controllers to work the fix, while the other half stayed on their consoles in mission control. So, instead of four teams for each console, only two were left, the teams of Chuck Lewis and Milton Windler.[15] For ten days, mission controllers worked at least twelve-hour shifts, usually 7:00 to 7:00, much like those working on the parasol.[16] With the loss of the meteoroid shield, the workshop lost a major form of thermal protection. The controllers had to set up a different attitude, the position of the station in relationship to its axes and the sun, for Skylab to keep the sun off the exposed area of the workshop. Unfortunately, the attitude to keep the sun off the workshop prevented the ATM solar arrays from absorbing energy. Thus, they had to compromise between overheating the workshop and having enough energy to keep Skylab flying.[17] They had to pitch up the OWS to keep it from overheating. One more problem with this scenario occurred because the only way to know the true orientation of the workshop was through a sun sensor. It had a narrow area in which the sun was supposed to remain so the controllers could know the exact orientation. By changing the attitude, the sun could not stay in the sensor and therefore they would not know the orientation. They realized that temperature sensors on the ATM could help because with the drastic difference between sun and shade they could tell which sensors were in sun or shade.[18] Interestingly enough, when the controllers reoriented the workshop for the arrival of the first crew, the sun ended up being exactly where the controllers had predicted, despite ten days of constant shifting using these methods.[19]

Due to the cold of space, the original plan called for the EECOMs to turn on heaters. John Aaron quickly recognized this not to be the correct course of action because of the heating already occurring. A brief argument ensued between controllers in Houston who had this heating data in front of them and the engineers in Huntsville who were not aware of the situation. Aaron simply did not turn the heaters on so as not to exacerbate the problem.[20] Quick thinking prevailed to stop the heat from becoming an even bigger worry.

During this time, another anomaly occurred when some of the charger battery relay modules, or CBRMs, began to stop working. These were important because the solar arrays charged the batteries so they could work in the shade. Without these on, the workshop could lose all power and not have power to be reactivated. On the next pass, the workshop would not pass over any tracking sites until it was over the United States, so some of the flight controllers had to call the stations in Guam and Hawaii and have them change their alignment and boost their power. Using these, they sent commands that reactivated the CBRMs and once again saved the workshop.[21] This is yet another example of controllers working behind the scenes to save the mission.

Many NASA employees would agree with Kenneth Young, who called the time spent fixing the workshop "the hardest [they] ever worked."[22] Others might agree with Melvin Brooks, who called it the "exciting part" of Skylab.[23] And, of course, some may agree with both, that it was the hardest work and also the most exciting work on Skylab. Some have also made the comparison of the launch and fix of the Skylab workshop to the problem and fix of Apollo XIII. Regardless of their viewpoint, most NASA employees probably would agree that this was a turning point in showing how they could handle an on-orbit accident and come up with a workable solution in a relatively small amount of time.

Once they were confident with the efforts of the men working on the parasol, NASA officials gave clearance for the first crew, SL-2, to go. Conrad, for one, was adamant on fixing Skylab and completing the mission. Since he had worked on the workshop in some way since 1968, he looked at it as his baby, much like an old motorcycle he owned as a child.[24] A final schedule revision placed the launch of Conrad, Kerwin, and Weitz for May 25, 1973.

SKYLAB II

Skylab II, SL-2, launched on May 25, 1973 at 9:00 a.m.[1] The three astronauts visually checked the workshop upon rendezvous. With great conviction, they reported that they could, indeed, fix the problem.

For their first EVA, Weitz hung out of the door of the CSM while Kerwin held his feet and Conrad flew the vehicle. Weitz attempted to hook the metal strap that was holding down the solar array. Conrad would then try to back away from the workshop with the CSM. Unfortunately, this attempt to free the solar array was unsuccessful. In fact, the controllers realized just how dangerous that could be.[2] So the crew had to quit for the day and, instead, dock to the station.[3] This docking, to add to their troubles, was anything but routine. For some reason, the capture locks for docking did not work. So, Weitz took control of the CSM while Conrad and Kerwin worked on the wiring. After roughly an hour of rewiring in the docking tunnel, they finally docked.[4] By the time the mission control launch team had worked through the first EVA and the docking, they had been on console for roughly twenty-two hours.[5] Apparently the long working days had not ended for the controllers.

The next day, the crew entered Skylab. Without the pivotal shield, the temperature was a rather warm 130^{o}F (54.4^{o}C). They therefore engaged in their next job, the deployment of a temporary parasol that would act in the shield's stead. Though they could not work non-stop due to the heat, by the end of the day, they had successfully deployed the parasol about two-thirds open. Overnight the temperature dropped to a more agreeable 90^{o}F (32.2^{o}C).[6] Although not yet at the optimal temperature, it was enough to let the astronauts continue to work the next day. The workshop would eventually cool down to the desired temperature.

The crew spent much of their first week or so dealing with storage and inventory, while also growing accustomed to the layout of Skylab and a typical workday with the many experiments. On June 7, the astronauts were finally allowed to attempt another EVA to fix the solar array. Conrad and Kerwin would leave the station, with Kerwin doing the actual cutting. After three hours and twenty-five minutes of hard work and gritty determination, they freed and deployed the array.[7] With this accomplished, the crew was able to return to normal, full-scale work. They were determined to work much harder in the final two weeks to make up for the time spent in the first two weeks both fixing the station and generally not working at a full pace due to the initial setbacks.[8] Indeed, this first crew constantly spent time fixing or repairing problems on the station. As a result, they could be christened the "Astronaut Repairmen", as they were by *National Geographic*.[9] This label would be true of all three crews, as it seemed as though the astronauts always had to fix something. This same determination and pride in their work continued with each crew. In the end, NASA's leadership could see that they definitely made the right decisions when picking these crews, for no one could accuse the mission members of working less than as hard as possible.

A normal day consisted of many tasks. Even when the station was not at full strength before they fully deployed the solar panel, the astronauts still accomplished as much as possible. Each day the astronauts would exercise, complete all their medical requirements, work on the ATM with solar studies, and do housekeeping chores.[10] Since they had trained together as a crew for almost three years, they worked together well. Perhaps one of the elements that helped them get along so well was their common Navy background. They also knew that they were there to do a job; they had to work together to complete the mission successfully. At one point, while trying some gymnastics in the circular area for the storage bins, Conrad dislocated his finger. Dr. Kerwin reset it, taped it, and they went back to work without telling the controllers in Houston.[11] This type of do-it-yourself teamwork exemplified almost all astronaut crews, but especially those on Skylab.

The first crew never asked for extra work. They did this purposefully, for they did not want to ask for too much and then have the flight controllers add too much work for the next crew.[12] They had free time, and like all three crews, they spent the majority of their free time looking out the window at the Earth. Apparently, most of the astronauts felt as though they did not know their geography as well as they should, but a chart on board the station defining their location proved helpful,[13] even if they may not have had enough time to see exactly where they were. The astronauts had other means of passing their free time available, but none appealed to any of the crews as much as viewing the Earth through the window.

Another important development revolved around communications between the astronauts and their families. Before Skylab launched, the issue of whether or not to let the crew have private conversations with their family surfaced. The astronauts wanted private talks, but the media fought against it, afraid that the crew would say something important and they, the media, would miss an important story. Since NASA decided against the crew and their families' privacy, the first crew said they would not talk if it could not be private. For the second and third crew, however, NASA relaxed the guidelines, and the astronaut and his family were allowed to talk together with one "trusted NASA" employee listening in and reporting anything out of the ordinary. While the media in general did not like this, they had to concede, and they never reported anything from the conversations. Fortunately for the astronauts, NASA officials changed their minds about the privacy issue, probably as a result of the first mission's successful completion, and allowed the astronauts to have private conversations with their families.

About a week before NASA scheduled the crew to come home, Mission Control asked the astronauts if they would not mind staying up in space an extra week. At that time, due to budget cuts, NASA was still unsure if the third crew would fly a mission, and they wanted to get the most data and results out of the station. While the SL-2 crew wanted to fly home on time, since space could not compare to the comforts of home, Conrad assured Houston that they were willing to help out any way that they could. Fortunately, a day or two later, NASA confirmed the third crew mission.[14] The SL-2 crew could leave on the twenty-eighth day as planned. The idea that the crew would not want to stay up longer seems unusual to outsiders since many people would pay, and some have, to be able to spend time in space. The other two crews did not seem to mind staying up for fifty-six and eighty-four days, respectively. Perhaps this feeling of longing for home was confined to just these three astronauts.

The last few days before leaving, the crew prepared the station for departure and stowed away objects. They undocked from Skylab on June 22 at 3:58 a.m. By 8:49 a.m., their Command Module was bobbing in the ocean waiting to be picked up. Conrad, Kerwin, and Weitz had set the spaceflight endurance mark at twenty-eight days, forty-nine minutes, and forty-eight seconds, with a total of four hundred and four orbits.[15] They had fully doubled the previous record. They successfully fixed the station so that it would survive the duration of the missions. Phil Shaffer commented that the first crew "saved the program" because "they took some risks that were above and beyond the call of duty."[16] Overall, Skylab II was a most successful mission.

The first crew in Skylab had one last interesting adventure after their mission ended. Shortly after their return, Dr. Chuck Ross broke the standard quarantine and allowed them to fly to California. There they met President Richard Nixon, who was hosting Russian General

Secretary Leonid Brezhnev and Chuck Conners, the star of television's "The Rifleman," at his Western White House.[17] By all accounts they had a mutually engaging time, and it was difficult to tell who was more excited by meeting whom. Sometimes the President's wishes take precedence over NASA rules.

SKYLAB III

A little over a month after the first crew had returned, the second crew, Skylab III, had finished training and was ready to launch. The first crew spent a few weeks after their mission finishing the medical experiments and debriefing. NASA passed on the information from those meetings to Bean, Garriott, and Lousma, in order to help them have a more efficient mission. The food preparation personnel also learned from a mistake mentioned by the first crew, and added more Tabasco Sauce to the menu to help with taste.[1] In the microgravity of space, taste buds act differently than on Earth and food loses much of its taste. As a result, condiments such as hot sauces and salt become more and more important to add some taste to food.

Skylab III, in their Saturn 1B, lifted off at 7:10 a.m. Eastern Daylight Time on July 28, 1973. It only took them a little under ten minutes to reach orbit.[2] Soon after they were visually observing the station. In fact, they docked nine hours after launch and actually entered the station only two hours after docking.[3] They were able to dock and enter much quicker than the first crew because neither did they have to worry about an EVA before docking, nor did they have the docking problems as the first crew encountered. Unfortunately, the mission soon would slow down to almost a crawl.

Whereas the first crew had been almost completely healthy, illness hampered the second crew. The entire crew became sick almost immediately and fell behind schedule. Instead of trying to continue their routines, and working to assuage the fatigue of the illness, NASA gave the astronauts permission to rest for the first three or four days. This actually gave the flight surgeons a chance to study the effects of space sickness.[4] After this rest period, the crew felt much better. Perhaps due to this slow start, they became an extremely efficient and hard-working crew.

Just a few days later, on August 2, alarms started showing that something was wrong with the command service module. Alan Bean had reported this just a few hours into the mission, but little attention had been paid to his statement. The CSM had four Control Moment Gyros [CMGs], thrusters, used to stabilize it around the service module. Two of the four began leaking, one of those completely out. They also happened to be on opposite ends of the service module, meaning they lost control in one axis.[5] Don Arabian, manager of the Program Operations Office, and Arnold Aldrich, deputy manager of Skylab, worked with the manufacturers at North American Rockwell Corporation to conclude that they probably could survive if the remaining two did not leak as well.[6] As a precaution, NASA began prepping Brand and Lind for a rescue mission, readied by September 5. In their simulations, however, the two showed that even with a crippled CSM, the crew could successfully return without harm. In effect, they talked themselves out of the chance to fly.[7] Even though it was not needed, the fact that they were ready to go proved that a rescue plan could become necessary and possible for such a mission. The two worked extremely hard and, in their own way, saved Skylab again. Thanks to the hard work of many individuals at NASA, they could avert another potentially disastrous problem.

Garriott and Lousma attempted the first EVA to install the permanent awning on August 6.[8] The original plan was for the EVA to take three and a half hours, but, due to unforeseen difficulties, they were out for six hours and twenty-nine minutes, a full three hours longer than planned.[9] This new shield had immediate effects, lowering the temperature the first night to 90^{o}F (32^{o}C) and shortly to the desired temperature around 70^{o}F (21^{o}C). The extended EVA once again showed that activities tended to take longer in space than they did in simulation. The astronauts of Skylab fell behind schedule mostly because of unrealistic goals and expectations set by the flight controllers.

The crew of Skylab III included very different personalities than the first crew. While Lousma and Garriott tended to love acting in front of the camera, Bean, the commander, was always trying to do more.[10] The commander remained highly motivated and focused. Lousma stood out as a "conventional Marine," staying loyal and friendly with the will to complete the job.[11] The first crew maintained that they made sure to eat all their meals together to keep the human contact.[12] This crew, on the other hand, rarely ate together, especially lunch. As Lousma said, since they were always rushing to work more and accomplish more goals, "things you needed to do the most to prolong your life…were the things that got the least priority: eating on time, sleeping on time, exercising on time."[13] They were extremely dedicated to their work, so they sometimes overlooked the most important concerns. Perhaps this is owing to a sense of being "on the clock" and always trying to get the most out of the limited time in space.

Even so, the crew found time to have some fun. One day, when Bob Crippen was CapCom, he heard a woman's voice calling him from Skylab. The voice identified itself as Mrs. Garriott; she had brought some things to the crew. She also mentioned that the California wild fires, taking place at that time, looked amazing. She then said that she had to go because someone was approaching the Command Module, where communications took place. Crippen went along with it, and told the other controllers what had happened. It was not until the twenty-fifth anniversary of the flight that Garriott explained that they had recorded it before the flight, adding Crippen's name and the California fires to make it seem more realistic. He also explained that Crippen knew about it. They had actually made a number of variations on tape using different natural events, playing the correct one depending on what was actually happening.[14] The amazing thing about it is that most of the flight controllers did not understand how that joke had been played until twenty-five years later. Jokes like this showed that they could have a good time while still working almost non-stop.

By the end of the mission, the crew had accomplished one hundred and fifty percent of their goals,[15] a remarkable amount considering all the problems with which they started. The crew returned on September 25, fifty-nine days, eleven hours, and nine minutes later. They set a number of records, including single mission endurance. Alan Bean accrued the most amount of time in space, a full 1,671 hours.[16] Perhaps even more important, they proved that man could last in space for that long a period of time. They also came back relatively healthy, even more so than the first crew. One can attribute much of their health to the exercise regime. At this time, Skylab would fly unmanned once again, waiting for the third and final crew to arrive to set even more records and accomplish even more research.

SKYLAB IV

The final Saturn 1B to Skylab launched on November 16, 1973 at 9:09 Eastern Standard Time.[1] Many surprises filled the weeks between the second and third crew. Astronomers had observed a new comet, Comet Kohoutek, in March that would achieve its perihelion (point closest to the sun) on December 28. NASA felt that this would be an exciting phenomenon, adding perhaps a once-in-a-lifetime chance to observe a comet above the atmosphere with astronauts and all the equipment on board the Skylab. As a result, in April NASA pushed back the launch of the third crew to November 9, and again delayed it to the 11th, thus giving time for the appropriate training.[2] Surely, the astronauts wanted as much training as possible, especially since they were an all-rookie crew.

Yet again the Skylab program had to deal with more setbacks. During a routine inspection of their Saturn 1B rocket on November 6, just five days before the scheduled launch, NASA employees found cracks on the fins. The administration quickly set workers to replace them. A week later they finished replacing all eight fins.[3] One reason given for the cracks was that the same rocket had been prepared months earlier for the possible rescue mission of Skylab III. The long period of time between initial preparation and the scheduled launch date meant there was simply too much weight on them for too long a duration.[4] In the true tradition of Skylab, the final mission had already dealt with obstacles before it even launched. This would not be the end of the problems.

Shortly before the launch, Gibson jokingly called their Saturn rocket “Old Humpty Dumpty” due to the necessary repairs, and some members of the media reported this statement. This angered some of the NASA employees, and they made sure that the astronauts knew how they felt. But around twenty minutes before the launch, the ground called the astronauts waiting in the command module and wished them “Good luck and God speed from all the king’s horses and all the king’s men.”[5] Evidently, the workers forgave them and, indeed, liked the joke. Such levity was reminiscent more of Bean, Garriott, and Lousma than Carr, Gibson, and Pogue.

The crew spotted Skylab about seven hours into the flight[6] and soon docked. Not long after, Pogue began to feel nauseous and vomited. Carr and Gibson worried that if Mission Control found out, they might stop the mission early and the crew surmised that Pogue would soon feel better. As a result, they decided not to say anything to the MOCR and just continue on as if nothing happened. Unfortunately for them, they did not know that a recorder taped their conversation and downloaded it to Mission Control. When the NASA officials found out what had happened, they were very upset with Carr’s judgement. Deke Slayton, the head of the astronaut corps, publicly reprimanded him.[7] The incident was not as simple as it sounds, however. Unlike the earlier commanders Conrad and Bean, Carr was a rookie. As such, he had neither the reputation nor the respect that the other two commanders already garnered with the flight controllers. The crew, however, rookie or not, certainly made a bad judgment call to choose not to tell MOCR about the illness. The crew definitely felt remorse for their less than forthright decision.[8] Nonetheless, the incident left a negative mark on the crew, one difficult to overcome.

When the crew finally entered Skylab, they found three dummies stashed around the station left by the earlier crew, still more evidence of the sense of humor of the second crew. That crew had worked at an amazing pace, completing, as noted before, one hundred and fifty percent of the mission goals. What Mission Control forgot, however, was how slow the mission had begun. As a result, the controllers started the third crew, from early on, with unrealistic schedules. The crew almost immediately fell behind, and Carr began to complain about the overload.[9] Carr, Gibson, and Pogue remained on an impossible pace for the first six weeks and then finally requested a rest, talking the situation over with the ground. From then on, the crew and flight controllers had an understanding. The schedule slackened off slightly.[10] In retrospect, for the first six weeks a great deal of hostility appeared to exist between the men of Mission Control and the three in Skylab. Most of this probably stemmed from the fact that Carr was inexperienced and felt overburdened with work. Perhaps Carr could have dealt with the illness situation better if he had more experience. At the least the flight controllers may have listened to him and respected his viewpoint.

The *New York Times* ran an article declaring the third crew "lethargic." The paper quoted officials saying that they were studying the lethargy of the third crew, and whether or not it could be fixed. They complained that they did not want to work on their day off. The controllers said that they had to lessen the workload, which was true, because the crew could not keep up with it. The *Times* in essence reported that they did not work as hard or as well as the first two crews.[11] Only three days later, the paper published a report that officials were "pleased" with the crew.[12] The news media seemed to jump on any opportunity to report hostilities or problems.

Beginning with the news reports of a lethargic crew, Skylab IV became by far the most controversial of the missions. One major work on the Skylab program, *A House in Space* by Henry S.F. Cooper, Jr., devotes a majority of its time discussing this controversial crew. While Cooper's history of the program touched on all three missions, it focused on the crew of Carr, Gibson, and Pogue, and their seeming insolence. Cooper's analysis inflamed many of the conflicts surrounding this particular mission.

From the first pages of *A House in Space*, Cooper attacked the crew. He wrote, "Flight controllers and others at the Space Center who had never been faced with reluctant astronauts before, openly talked of them as being lethargic and negative."[13] Again, "Gibson…had a square jaw that apparently never stopped moving the whole time he was in space" and he "was perhaps the contrariest, bitchingest astronaut that ever departed vertically from Cape Kennedy, and his two crewmates were in the same category."[14] Of the other two, "Carr and Pogue grew thick, revolutionary-looking beards aboard Skylab…which, combined with the blistering language from the space station, made them [the flight controllers] uneasy."[15] Finally, "the remarks of all three members of the third crew continued to have a barracks-room grumpiness from the beginning of the mission to the end."[16] Each of these are just a sample of the openly hostile remarks made against the third crew. Cooper even included an underlying message that the "revolutionary" beards made those in MOCR apprehensive because those beards did not conform to the "clean-cut" image of NASA and could even be likened to the Soviets in Russia. At this time, the Cold War still dominated the country's mindset, and to even imagine such an American icon resembling a Communist would make anyone "uneasy." A suggestion like this was much more grave at the time that the book was published than in today's world. To make matters worse, the author rarely ever backed up his arguments, except to say that this negativity grew from their concealment of Pogue's sickness.

NASA instructed each of the crews beforehand to tell the truth about Skylab's habitability. They were supposed to be critical, offering advice to improve the station. Each crewmember could find something to complain about. When Lousma spoke out against the lids on the food, Cooper remarked that he "at times sounded like a member of the third crew."[17] That was an unfair, disparaging comment that had no basis in truth. Lousma was doing his job, telling the NASA officials what he thought about the lids. Not only did the author rebuke him, but also the third crew as well.

Interestingly, though, Cooper seemed to change his mind about the crew farther along in the book. He stated that the third crew "griped" and "made so many mistakes and fell so far behind," but there was "nothing seriously the matter with the astronauts at all." Instead the problem "lay with the ground itself" because they "started these astronauts off at too fast a pace."[18] Indeed, Cooper blamed flight director Neil Hutchinson for any problems because he pushed the crew thinking they were lazy.[19] The reader hardly knows what to believe: was the crew really that bad, or could one blame tensions and dissension on the flight controllers in Houston?

Years later, Neil Hutchinson admitted the flight controllers made a mistake by pushing the third crew too hard.[20] Phil Shaffer agreed that the third crew was pushed too hard too early, adding that the all-rookie crew was not "adequately supported" pre-flight, making it a more awkward mission than the first two.[21] In fact, most flight controllers, including flight directors Milton Windler and Chuck Lewis, agreed upon reflection that they had mistreated the third crew. More than likely, the tension between the crew and the controllers occurred due to unreachable goals set by the controllers and perhaps some attitudinal problems from the crew.

Another issue about this flight was the so called "Space Strike." Around the sixth week in Skylab, the crew said that they needed a day off to rest. They also wanted to talk things out with the controllers in Houston. Everything seemed to be worked out, but the astronauts also decided that only one of them would talk to the ground at any one time. During one whole pass over the United States, they forgot to turn the radio back on, not realizing until later that they had not heard from Houston. The media heard about this and dubbed it the "Space Strike," saying that the astronauts were non-cooperative. Cooper also mentioned this in his book. Astronaut Dr. Gibson took offense to this because Cooper, and other media members, never actually spoke to the astronauts about the so-called strike. Cooper, in fact, based his narrative solely on the communications tapes.[22] The tapes are valid sources for scholarly works. They contain the exact words of the astronauts and ground crews without any interference. To use them exclusively, however, can lead to trouble because only using one source for a work will always make it biased, and the total lack of any correspondence with the people in the events means situations could be taken out of context. Consequently, without actually speaking with those who took part in the events, how could Cooper arrive at a clear and accurate picture?

Other secondary sources, such as more recent publications like Don Shayler's *Skylab: America's Space Station*, corroborate that this crew had problems, perhaps more so than the first two, but few treatments are as extreme as Cooper's. While the crew certainly struggled at the beginning of the mission, this can mostly be contributed to the less than admirable start to the mission. After the incident of hiding Pogue's sickness, many media members seemed to want to make the astronauts out to be "bad guys." For the most part, they were doing their jobs by complaining about conditions on board Skylab. The amount of complaining, however, probably went too far and damaged their reputation. The imagined "Space Strike" event did not help their standing in the eyes of many critics. NASA, however, stood by the astronauts and allowed them to complete their record-breaking mission.

Despite all the problems, one may suggest that this final crew was the most productive of all, accomplishing even more than the crew of Alan Bean. Simply on percentage of time alone, the third crew spent around forty percent of their time on experiments, the second crew almost thirty-nine percent, and the first crew almost thirty-eight percent. That slight percentage difference is made even greater when physical training is factored in, since the third crew spent a full percentage point more time on physical activity than the second crew, and over three percent more time than the first crew.[23] Each successive crew spent more time on experiments generating more output. The third crew easily spent the highest percentage of time on research and outperformed the first two crews (full table found in Appendix A).

On January 11, 1974, NASA told the crew that they would, indeed, stay at Skylab for the full eighty-four days. This meant that, after forty-eight days, every day, every hour, and every minute that they stayed in space was another record. On February 3, Carr and Gibson departed for the final EVA of Skylab, this time a five hour, nineteen minute long spacewalk to collect all the samples and film from outside the station. Just before leaving, the crew boosted the station into a higher orbit in an effort to help it last into the 1980's. They also left a few resources in the station in case NASA scheduled another mission, perhaps with the planned Space Shuttle, to redock with Skylab. On February 8th, they finally left Skylab, flew around taking more pictures, and landed in the ocean only five hours later. The mission had lasted a total of eighty-four days, one hour, fifteen minutes, and thirty-two seconds.[24] Their record lasted four years until Cosmonauts Georgi Grechko and Yuri Romanenko on Salyut 6 were in space for over ninety-six days. Behind them, the crew of Skylab IV left a legacy of science and research. Man had learned, time and again, how to work through adversity in space flight. Each mission had had its share of trials, and each presented NASA in a favorable light, despite some controversies.

RESEARCH

On a typical day aboard Skylab, the three astronauts awoke at 6:00 a.m. They then dressed and shaved before eating breakfast around an hour later. After breakfast, one of the crew would head to the ATM for solar observations, while the other two dealt with other experiments, such as medical or maneuvering units.[1] The average crew member spent one to one-and-one-half hours on the exercise bike each day, but each crew increased their amount throughout the program (see data in Appendix A).[2] Meanwhile, the crew would conduct solar observations through shifts throughout the day, stopping for lunch when they could. When all the work was done, they could attend to a "shopping list" of experiments or repairs needed to successfully complete the mission. All would stop for dinner around 6:00 p.m., after which the crew dealt with household chores and reviewed the next day's schedule that Mission Control sent up on the teleprinter. In the evening they had some time for recreation, and generally each would have a private conversation with the flight surgeon to discuss the medical experiments and any health issues.[3] While a typical day may not seem very exciting, enough activity kept the astronauts busy and brought them closer to reaching their goal of a successful mission. Many times, of course, something interrupted the day, such as an EVA or a necessary repair. NASA employees truly tried their hardest to get the most out of the agency's investment.

NASA, and humanity as a whole, gained a number of advances from the Skylab missions. Outside of the experiments, the workshop held the first truly computerized data storage system, a necessity for most businesses today.[4] One of the important corollary experiments was the test of a maneuvering unit for space walks. The crews flew for a total of twelve and one-half hours. NASA deemed the test "very successful" and recommended it for use on the shuttle.[5] From this came the Manned Maneuvering Unit [MMU], a significant part of subsequent EVAs.

Eugene Kranz calls Skylab "probably the most productive era of space science in the history of the [NASA] program."[6] Each of the three major areas of scientific interest saw intriguing and major developments.

In the medical experiments area, Robert Heselmeyer notes that they produced a good database for long duration space flights.[7] Carolyn Huntoon, who worked on a life sciences experiment, believes it is "the best data in the world on people exposed to weightlessness" and that "to this day, there is nothing that comes close."[8] And again, from Carl Shelley, Chief of the Space Science and Technology Branch, "the medical database gathered off Skylab is still probably the best one."[9] Dr. Charles Berry, Director of Life Sciences, gives some further insight by detailing that they did not find an answer to calcium loss, but they did learn a great deal about red blood cell loss, among other anomalies.[10] Little doubt remains as to just how important the medical science of Skylab was to the field.

R. Bryan Erb, the principal investigator for the Earth Resources Experiment Package, says that they "got some excellent data" despite a limited range because "the data quality was much better" than other sources.[11] That higher quality data allowed for some high definition photographs of cities such as New York City and Washington, D.C., that could be used for a variety of purposes.[12] Robert Stevenson indicates some other interesting examples. For instance, crews on Skylab observed eddies in the Caribbean Sea that had never been measured. This allowed the Navy to account for some acoustic problems so that they could address those problems.[13] He also mentions that the astronauts observed plankton in the Falkland Current stretching 1,500 miles. Previously there had only been one obscure reference to plankton in that current.[14] More new findings came from EREP data. They investigated such things as strip mining, ore deposits, and natural disasters. The findings even helped Venezuela discover oil, which would elevate the country's status and help to offset the big business of Middle Eastern oil. They even witnessed a secret Chinese nuclear test.[15] John Llewellyn once said that he "probably learned more doing [Skylab] than anything [he] ever [did] at NASA" while working on EREP.[16] Even the veterans of the Apollo program could increase their learning curve while working on this program.

Skylab brought some exciting developments to solar astronomy as well. Marlowe Cassetti pointed out that since it was above the Earth's atmosphere, the Apollo Telescope Mount could view the sun in spectrums that cannot be viewed within the atmosphere.[17] Don Lind perhaps exaggerated somewhat when he claims that Skylab rewrote solar physics and astronomy.[18] Nevertheless, important contributions did result from this work. Skylab made significant scientific strides in each area of research and experimentation. These contributions help to provide some context to the importance of this program.

FROM SKYLAB TO THE SHUTTLE

NASA discussed the possibility of returning to Skylab only for a short time. They soon deemed another visit to reboost it for a better crash landing with the Earth too risky and too complicated, since it would require a somewhat intricate EVA.[1] There was also talk that after the new shuttle was ready to launch, a crew would rendezvous with the station. For this mission, the administration picked Fred Heise and former Skylab astronaut Jack Lousma.[2] Ultimately, the discussion would become moot since Skylab left orbit years before NASA fully completed the Shuttle.

The men who worked on Skylab have varying ideas about whether or not it should have flown longer. Donald Arabian believes that manned missions flew to Skylab for only one year because it was not worth more.[3] Kenneth Kleinknecht goes even further by arguing that they accomplished all their goals on Skylab. He even says that the fight to fly again to Skylab was "ludicrous."[4] M.P. Frank, on the other hand, believes it was "short-lived."[5] Jones Roach, Deputy Chief of the Flight Control Division, says it is a "shame" there was not enough money to keep Skylab flying.[6] Eugene Kranz calls "the abrupt termination of Skylab, after only three manned missions, almost heretical."[7] John Aaron regrets the loss of Skylab because it was already in space, it had more volume than the current station, and they should not have had to start from nothing when building the station.[8] Today, he argues, NASA could be further along in space exploration if they had continued to use Skylab, and the agency could have saved a lot of money by using it.[9]

NASA built a second Skylab, also known as Skylab II or Skylab B. Plans developed to launch it, until the NASA administration cancelled the program in August 1973,[10] presumably due to budget constraints and a wish to move on to the shuttle. Garriott thought this was a mistake. He mentioned that the second Skylab could have allowed even a longer duration flight. Since this did not come about, the second best place for Skylab II would become its resting-place, the Smithsonian Institution National Air and Space Museum in Washington, D.C.[11] Don Lind, the backup and rescue astronaut for Skylab, even petitioned an NASA Administrator to fly the second Skylab. He reasoned that, with all the money already spent on it, they should at least get something back in the form of more scientific experiments. The Administrator simply stated that it would set the shuttle back a year.[12] Incidentally, the first shuttle launch would not be for another eight years. Since the second workshop did not launch, one can only guess what another manned crew could have accomplished. It is amazing to think that all the hardware was constructed at great cost, yet it was never used. Such are the realities of working in government bureaucracies.

In February of 1978, flight controllers working in Bermuda regained some communication with the dying space station. They frantically moved to many centers across the world over the next summer, only to learn that in December NASA cancelled the mission to revisit Skylab.[13] This happened despite the efforts of men like George Jeffs, a Vice President of the Apollo Command/Service Module at North American Rockwell Corporation, who wanted to reboost the workshop with another CSM.[14] Now all that was left for controllers was to try to predict where it would land. Vance Brand and Don Lind trained to use a CSM to reposition the workshop for a better return area.[15] They instead had a small amount of power left in the station to try to reposition it for a better landing.

On July 12, 1979, Skylab met the Earth. The decaying orbit sent the station falling down over the western portion of Australia and into the surrounding waters, slightly off the predicted fall. Luckily for everyone involved, pieces landed only in sparsely populated areas of a friendly nation. Skylab had completed 34,980 orbits and left a debris field 40 by 2,400 miles [64 by 3,860 kilometers]. Collected pieces went to NASA for examination.[16] A casual observer can now find pieces of it for sale on eBay occasionally.

After Skylab, NASA moved on to the nine-day mission of the Apollo-Soyuz Test Project, in which Vance Brand (Skylab backup and rescue astronaut) and Deke Slayton (of the Original Seven) finally flew in space.[17] For NASA, however, the future lay in the new, reusable, space shuttle. In fact, some engineers and scientists tried to move straight from Apollo to the shuttle project, thinking that anything else was a dead end and a waste of time.[18] The new shuttle brought some of the public's interest back, since NASA was again seen as on the cutting-edge.

Of the nine Skylab astronauts, only Owen Garriott, Jack Lousma, and Paul Weitz flew in space again, this time in the shuttle. Weitz maintained that he went through the same basic training for both Skylab and the shuttle, that not much had changed.[19] Garriott said that while the launch of the Saturn rocket and the shuttle were relatively the same, the re-entry was completely different.[20] Of course, for Skylab they landed in a capsule in the water, whereas the shuttle landed like a glider on a runway. On the other hand, Lousma indicated that the launches were actually very different. The Saturn rocket was a stop-and-go launch because of the stages, but the shuttle was a continuous movement out of the atmosphere.[21] Obviously there were some major changes between the two projects, but each seemed to adapt well to the new format. Such adaptations are the key to survival at NASA. For the time being, at least, the shuttle was here to stay. The days of the one-shot-only spacecraft would not be revisited for some time.

To summarize, as Dale Myers, the Associate Administrator of the Johnson Space Center during Skylab, says, "I don't think Skylab ever gets the credit it should get. It was just an immensely productive program."[22] The conclusion of Skylab brought at least some controversy in the ranks of the NASA employees. Those in charge wanted to move on to the seemingly endless possibilities of the shuttle rather than stay with a potential workhorse space station. In the end, perhaps the legacy of Skylab are the extremely productive experiments, many of which have never been duplicated.

LESSONS LEARNED

From the beginning, NASA designed Skylab as a program that would lead to other projects. Since the main objectives of Skylab were science and research, many of the outcomes focus on those two fields. The space station naturally led to groundbreaking achievements and new ways for NASA to run missions in the future. This section will highlight a few of the most important lessons learned.

After each mission, a crew debriefing allowed for the assimilation of some lessons learned. As an example, the astronauts could learn from Kerwin, who became seasick after splashdown, most likely because he drank a cherry drink.[1] He also suggested that for the following missions non-essential teleprinter messages should be transmitted only once or twice a day, rather than continuously interrupting the astronauts' course of work.[2] The first crew mentioned that food palatability in space tended to be more extreme than on Earth, either negatively or positively.[3] The second crew specifically highlighted their conversations with their families as very positive.[4] The third crew, as might be expected, mentioned a few aspects that could be handled better. They asked for more flexibility with the flight controllers.[5] Pogue remarked that the controllers were too impersonal in their interactions with the crew members.[6] Each crew brought its own perspective and certainly future missions can learn from their experiences.

In fact, the space agency embarked on a systematic lessons-learned program beginning with Skylab on April 30, 1974. NASA employees concluded, among other things, that they needed a system to verify teleprinter messages and to make sure that they had received the complete message.[7] Also, for future missions, mission control could work equipment or experiments while the crew was asleep or eating for even more scientific output.[8] During mission control team meetings, the presence of a Public Affairs Officer helped the dissemination of accurate information to the press.[9] NASA also found that, other than low humidity, habitability conditions were acceptable.[10] Finally, the paper suggested an hour of non-activity before sleep for the crew.[11] Again, is just a sample of the many lessons learned.

On July 18, 1974, NASA compiled another list of lessons learned. For instance, the presence of man in space as an observer and a repairman proved invaluable to the Skylab program.[12] The lack of a video uplink taught the agency the need for such capability, especially to teach the crew repair procedures.[13] While the food was better than on previous missions, a lack of variety led to an idea for a "pantry-style food storage system" which would allow astronauts to select their desired food for the day.[14] In the area of clothing, a shirt and pants were preferable to a suit for comfort.[15] Skylab also could be considered in some ways a turning point in the area of Extravehicular Activities. It showed the importance of foot and body restraints both inside and outside the vehicle. NASA also found that standardization was the key to successful EVAs.[16]

NASA later released, on June 5, 1984, a thirty-two page booklet listing the lessons learned on a wide variety of aspects of the Skylab mission. This included the finding that "good muscular condition required at least an hour a day of deliberate exercise per man."[17] This was key to maintaining the health of crews on long-duration missions. NASA also concluded that large windows for observation of the Earth were good for crew morale and relaxation. Repeatedly stated, the window was often the most popular area during any time of relaxation for each of the crews.[18] International Space Station designers have integrated this concept in their plans.

For the first time in NASA's history someone other than CapCom talked to the Skylab astronauts while they flew in space. At one point in the third mission, Dr. Robert M. McQueen, a Flight Surgeon, spoke with Gibson about one of the experiments.[19] While this type of interaction had never occurred before, it now is more commonplace. Flight surgeons now speak directly to the astronauts somewhat frequently while they fly in space.

The relationship between scientists and astronauts changed for the better during Skylab missions. Before they flew, those in charge of experiments tended to doubt whether or not the astronauts could complete the experiments correctly. By the end of the missions, the scientists seemed surprisingly pleased with the dedication of the astronauts and even thanked them for their hard work.[20] Indeed, Dr. Kerwin felt as though they were not guinea pigs, but rather co-investigators.[21] Probably the most skeptical of all scientists participating in this mission were the solar astronomers who did not want the astronauts to be in charge of pointing the ATM at the sun. In the end, however, Harry Cooper acknowledges that the scientists "were delighted at the way every time anything interesting occurred on the sun…the astronauts had focused on it."[22] Perhaps this relationship changed for the scientists and experimenters once NASA began accepting scientist-astronauts and striving for research in space. Certainly the hard work and commitment to their mission helped cement this affinity.

When asked what were the most important contributions of Skylab to NASA, the astronauts answered in a variety of ways. Carr maintained that they helped most in the field of medical studies, especially by living for an extended period of time in microgravity.[23] Kerwin stated that they aided most "the habitability, the diet and exercise, and the workday structure" for any future missions such as the International Space Station.[24] Garriott listed such contributions as the solar observations, long duration weightlessness, the importance of exercise in microgravity, and the idea that artificial gravity may not be necessary for future missions to places like Mars.[25] Finally, Conrad asserted that the main lesson was that practical applications of Skylab, such as Earth observations and a computerized inventory, proved that NASA could benefit all mankind.[26] A variety of important discoveries resulted from America's first space station.

With Skylab, NASA also realized that it could perform meaningful programs on a smaller budget.[27] Through the Apollo program, the United States Government had allocated almost any amount of money and resources needed for reaching the Moon. The federal government still has not matched this level of spending. The ability to work on a tighter budget would become critical to the space agency.

During Skylab, the different NASA centers around the country also had to learn how to communicate more effectively and how to work together to accomplish common goals. After NASA became aware of the problems during the launch of Skylab, many of the centers pulled together to learn how to fix them. Certainly, Huntsville and Houston received the most recognition for the work, but many of the others contributed as well. As some Skylab personalities, such as Garriott and Kerwin, have said, the level of cooperation has never been matched. Garriott called it "sort of the golden era" of inter-center cooperation.[28] From the beginning of Skylab, the amount of interaction among centers was greater than it had been during any previous program. The project originated at the Marshall Space Flight Center in Huntsville, but also included major contributions from Houston and Cape Canaveral. Today's success in cooperation among NASA centers may not be as remarkable as it was during Skylab, but one certainly can consider the inter-center relationship more efficient than it was in the time before the space station.

The Skylab missions also taught NASA some key lessons on habitability. The adaptability of clothing and the necessity for more comfortable attire led to changes in the post-Skylab wardrobe of astronauts in space.[29] Also for the first time each astronaut had an individual sleeping compartment, due to the increased volume of the station.[30] While today's astronauts may not benefit from the same luxury, the idea of the need for privacy at certain times still holds true. For the most part, the astronauts agreed that the food on Skylab was much better than on previous missions. This resulted mainly from the addition of food warmers. Even so, the final two crews to Skylab learned from one mistake by the first crew. Since taste buds are not as effective in the microgravity of space, the second and third crews took with them more Tabasco Sauce to add some taste to the food.[31] Tabasco Sauce, salsa, and salt are still main ingredients to enhance the flavor of food in space. A habitability study based on Skylab in 1977 recommended only a ten-hour workday for future missions.[32] This recommendation has not always been followed. The same study also recommended a ninety-day maximum for future missions.[33] This standard obviously was not adhered to since the current record is over four hundred days, though most of the over-ninety-day missions are Russian. Indeed, most ISS crews now stay in space more than twice that recommended time.

Marlowe Cassetti listed a number of lessons learned from this mission. First, the MOCR computers had keyboards rather than just buttons, which allowed for more interactions by the mission controllers. This key change to Mission Control greatly changed space flight from the ground's perspective. The addition of satellite relays allowing for more contact between the controllers and the workshop was another important change for future missions. Finally, NASA learned the potential effectiveness of astronauts in troubleshooting. The first crew especially, with the deployment of the parasol and the releasing of the solar panels, proved the usefulness of humans in space. Cassetti directly relates this achievement to the use of astronauts twenty years later in the repair of the Hubble telescope.[34]

Other flight controllers have noted some lessons from Skylab. Eugene Kranz said that NASA learned an important lesson about the psychology of long-term space flights.[35] They are inherently different than the short-term missions of Mercury, Gemini, and Apollo. Skylab was a marathon compared to the relative sprints of earlier missions. One could apply this change to the current International Space Station. Phil Shaffer claimed that “it produced a tremendous amount of very valuable information about the Earth and about the sun and about space flight and about the human physiology, metals and materials, etc, etc.”[36] In other words. Skylab’s lessons crossed into almost every area of space flight. Two of the flight directors, Milton Windler and Chuck Lewis, stressed the importance of the “Science Czar.” He served as someone who could work with both the flight controllers and the scientists, so that the flight directors did not have to make decisions on the importance of different scientific experiments.[37] Bob Parker and later Bill Lenoir served in this position and helped to stop potential quarrels between those two communities.

Ed Fendell points to two major lessons from Skylab that may be applied to the ISS. Due to the long hours, the attrition rate of mission control was much worse than on the shorter missions. On a more positive note, NASA can learn something from Skylab about how to collect and process large amounts of data.[38] For more lessons that apply to the space station, Tommy Holloway, a member of flight planning, tried to learn from the mistakes of the mission control scheduling so that in the future people will not have to work as many “odd hours” and can have “more of a family life.”[39] George Franklin of the Spacecraft Design Division added that, because of Skylab, they realized that astronauts could sleep just about anywhere when in space.[40]

Perhaps this concept has attributed to the lack of personal living areas on either the shuttle or space station. John Aaron believed they learned to slow down the planning on long duration missions so as not to overload the astronauts.[41] They also learned how to maintain a station in orbit through EVAs and other methods, and that the ISS has hand holds for EVAs due to problems with Skylab.[42] Finally, Kenneth Kleinknecht stated that Skylab taught NASA engineers many lessons about testing systems, notably environmental testing, for future, and especially long-duration, missions.[43]

There are also some lessons that NASA should have learned from the experience of Skylab, but instead have become repeated mistakes in subsequent missions. Kenneth Young pointed out one in particular. Those who schedule the astronauts onboard the ISS did not learn from Skylab that they cannot schedule every moment of the astronauts' time.[44] Flight controllers must allow some leeway in the astronauts' itinerary. John Aaron says that NASA did not learn the importance of volume when making a space station. Volume helps with waste management and noise reduction, among other things. NASA administrators, when working on the design of the ISS, instead listened to the fallacy that higher volume translates to higher cost.[45] All of the lessons described here, those accepted and rejected, should have the potential to educate everyone involved in future space flight in an attempt to avoid past mistakes.

CONCLUSION

While the collective Skylab missions themselves only lasted almost a year, their effects are long lasting. Enormous amounts of data came from the numerous scientific experiments and other research aspects of the mission. Likewise, the ability of the astronauts to criticize flaws and make suggestions for the future led to more productive missions. The men went on to take part in many organizations, but generally they stayed close to the space agency. NASA even asked some of them for help when designing the International Space Station. One could even say that the lessons learned on Skylab proved invaluable to the ISS and that it could not have been constructed without the previous experience on Skylab. Most importantly, these men demonstrated that humans could last through long duration missions in microgravity. Through dedication to reach a goal and teamwork, they successfully completed what should be the first in a long legacy of human long duration endeavors in space. These men, from various regions of the country and from different socioeconomic backgrounds, came together to make a lasting mark on America's space program. These missions were not wasted ventures, but rather gave more understanding of the human condition. May humanity never lose its zeal to conquer the invincible and study the fascinating.

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38. Edward Fendell, oral history interview with Kevin M. Rusnak, October 19, 2000, JSC Oral History Project, University of Houston-Clear Lake JSC History Collection, 66-67.

39. Tommy Holloway, oral history interview with Rebecca Wright, July 24, 2002, JSC Oral History Project, University of Houston-Clear Lake JSC History Collection, 15.

40. George Franklin, oral history interview with Kevin M. Rusnak, October 3, 2001, JSC Oral History Project, University of Houston-Clear Lake JSC History Collection, 57.

41. Aaron, 89.

42. Ibid., 99-100.

43. Kleinkencht, 5.

44. Young, 7.

45. Aaron, 90-91.

APPENDIX A

HOURS FOR EACH MISSION

Activity	Skylab 2		.Skylab 3		Skylab 4	
	Hrs.	%	Hrs	%	Hrs	%
Medical	145.3	7.5%	312.5	8.0%	366.7	6.1%
Solar Observations	117.2	6.0%	305.1	7.8%	519.0	8.6%
Earth Resources	71.4	3.7%	223.5	5.7%	274.5	4.5%
Other Experiments	65.4	3.4%	243.6	6.2%	403.0	6.7%
Sleep, Rest	675.6	34.7%	1224.5	31.2%	1846.5	30.5%
Pre/post Sleep, Eating	477.1	24.5%	975.7	24.9%	1384.0	22.9%
Housekeeping	103.6	5.3%	158.4	4.0%	298.9	4.9%
Training, Hygiene	56.2	2.9%	202.2	5.2%	384.5	6.4%
Other (EVA)	232.5	12.0%	279.7	7.1%	571.4	9.4%
Total	1944.3		3925.2		6048.5	

From: Skylab Statistics. Kennedy Space Center. http://www-pao.ksc.nasa.gov/kscpao/history/skylab/skylab-stats.htm.

APPENDIX B

SKYLAB EVAs

Date	Astronauts	Purpose	Duration
5/25/1973	Weitz	Stand-up EVA	0:33
6/7/1973	Conrad and Kerwin	Free Solar Array	4:31
6/19/1973	Conrad and Weitz	Replace ATM film	1:37
8/6/1973	Garriott and Lousma	Deploy permanent heat shield and replace ATM film	6:31
8/24/1973	Garriott and Lousma	Replace ATM film	4:30
9/22/1973	Bean and Garriott	Retrieve parasol sample and replace ATM film	2:42
11/22/1973	Pogue and Gibson	Replace ATM film	6:33
12/25/1973	Carr and Pogue	Replace ATM film and photograph comet	6:51
12/29/1973	Carr and Gibson	Retrieve micrometeoroid shield piece and photograph comet	3:30
2/3/1974	Carr and Gibson	Collect all samples and ATM film	5:19

APPENDIX C

LIST OF ACRONYMS

AAP – Apollo Applications Program

AES – Apollo Extension System

AM – Airlock Module

ASTP – Apollo-Soyuz Test Project

ATM – Apollo Telescope Mount

CapCom – Capsule Communicator

CBRM – Charger Battery Relay Module

CMG – Control Moment Gyro

CSM – Command/Service Module

DoD – Department of Defense

EECOM – Electrical, Environmental and Communications

EGIL – Electrical, General Instrumentation, and Life Support System

EREP - Earth Resources Experiment Package

EVA – Extravehicular Activity

EXP – Experiments officer

FIDO – Flight Dynamics Officer

FLIGHT – Flight Director

FOD – Flight Operations Director

FOMR – Flight Operations Management Room

GNS or GNC – Guidance Navigation and Control System

GSFC – Goddard Space Flight Center

GUIDO – Guidance Officer

HQTRS – Headquarters

INCO – Instrumentation and Communication Officer

ISS – International Space Station

IVA – Intravehicular Activity

JSC – Johnson Space Center

LM – Lunar Module

LV – Launch Vehicle officer

MDA – Multiple Docking Adapter

MED OPS – Medical Operations

MMU – Manned Maneuvering Unit

MOCR – Mission Operations Control Room

MOL – Manned Orbiting Laboratory

MSC – Manned Spacecraft Center

MSFC – Marshall Space Flight Center

NACA – National Advisory Committee for Aeronautics

NASA – National Aeronautics and Space Administration

NETWORK – Network controller

NOAA – National Oceanographic and Atmospheric Administration

O&P – Operations and Procedures

OWS – Orbital Workshop

PAO – Public Affairs Officer

POCC – Payload Operations Control Center

ROTC – Reserve Officer Training Corps

SCH – Space Center Houston

SKYCOM – Skylab Communications

SMAG – Space Medicine Advisory Group

SMEAT – Skylab Medical Experiment Altitude Test

SPAN – Spacecraft Performance Analysis room

TELMU – Telemetry, Electrical, EVA Mobility Unit officer

USAF – United States Air Force

USMC – United States Marine Corps

USN – United States Navy

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